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ABSTRACT

The northern pike *Esox lucius* population in Harding Lake in interior Alaska was studied during spawning in May and June 1991 and 1992. The abundance of northern pike 300 millimeters and longer was estimated with two-sample mark-recapture experiments. Abundance in 1991 was 2,086 (standard error = 405); about 2.1 fish per hectare. Abundance in 1992 was 2,868 (standard error = 353); about 2.9 fish per hectare. Generally, abundance of northern pike 450 millimeters and longer was about 1,500 from 1990 to 1992; however, the abundance of small northern pike (300-449 millimeters) increased from about 800 to about 1,400. The rate of survival of northern pike 300 millimeters and larger from 1990 to 1991 was 0.97 (standard error = 0.18). The rate of recruitment from 1991 to 1992 was 2.23 (standard error = 0.33).

KEY WORDS: Northern pike, *Esox lucius*, Harding Lake, abundance, mortality, recruitment.

INTRODUCTION

The estimated harvest of northern pike *Esox lucius* by anglers in Alaska has ranged from 11,982 in 1977 to 29,611 in 1991 (Figure 1; Mills 1991). In 1990, about 72% of the northern pike harvested in Alaska were from the Arctic-Yukon-Kuskokwim Region (AYK). In the Tanana River drainage, northern pike is second only to Arctic grayling in catch and effort (days fished) for indigenous game fish. The proportion of northern pike caught and released in Alaska in 1990 (0.82) was second only to Arctic grayling (0.85; Mills 1991). In 1989, the largest harvests of northern pike in Alaska were Harding Lake (1,764), Minto Flats and the Chatanika River (1,684), Healy Lake (1,393), George Lake (882), and East Twin Lake (832). All these fisheries are in the Tanana River drainage. In 1990 and 1991, the estimated harvest of northern pike from Harding Lake was 591 and 1,487, respectively. In 1991, about 4,600 northern pike were caught in Harding Lake and about 3,100 were released.

More northern pike were harvested than all other game fish combined in Harding Lake from 1983 through 1989 (Table 1). In 1990 and 1991, northern pike made up 44% and 48% of all game fish harvested from Harding Lake. Of all game fish caught and released in Harding Lake in 1990 and 1991, 59% and 55% were northern pike. Recent efforts by the Alaska Department of Fish and Game (ADF&G) to direct more fishing effort to Harding Lake by stocking Arctic char *Salvelinus alpinus*, Arctic grayling *Thymallus arcticus*, and rainbow trout *Oncorhynchus mykiss*, along with the trend of increasing use and harvest levels of northern pike has generated concern for the population of northern pike in Harding Lake.

In 1990, ADF&G initiated a study of the northern pike population in Harding Lake. The goal was to estimate population abundance, recruitment, and age and length compositions of northern pike for several years. The first estimate of abundance in spring 1990 was 1,283 (SE = 145) northern pike 450 mm fork length (FL) and larger (Burkholder 1991). The density was 1.28 northern pike per hectare and was the lowest density documented for northern pike in an interior Alaskan lake. Northern pike have been the basis of the sport fishery in the lake and it is unlikely that the population can sustain such high harvest levels in what is very likely a recruit-based fishery. Prior to 1987, 10 northern pike less than 30 inches, and two northern pike 30 inches or greater could be taken by anglers in the Tanana drainage. In 1987, more restrictive regulations were implemented drainage-wide for northern pike. These regulations reduced the bag limit to five northern pike, with only one over 30 inches. In spring 1991, the following special regulations were implemented for northern pike in Harding Lake:

1. Harding Lake was closed to the taking of fish by spear or bow and arrow.

2. Northern pike can not be possessed or retained from 1 April through 31 May; all northern pike caught between these dates must be released immediately.

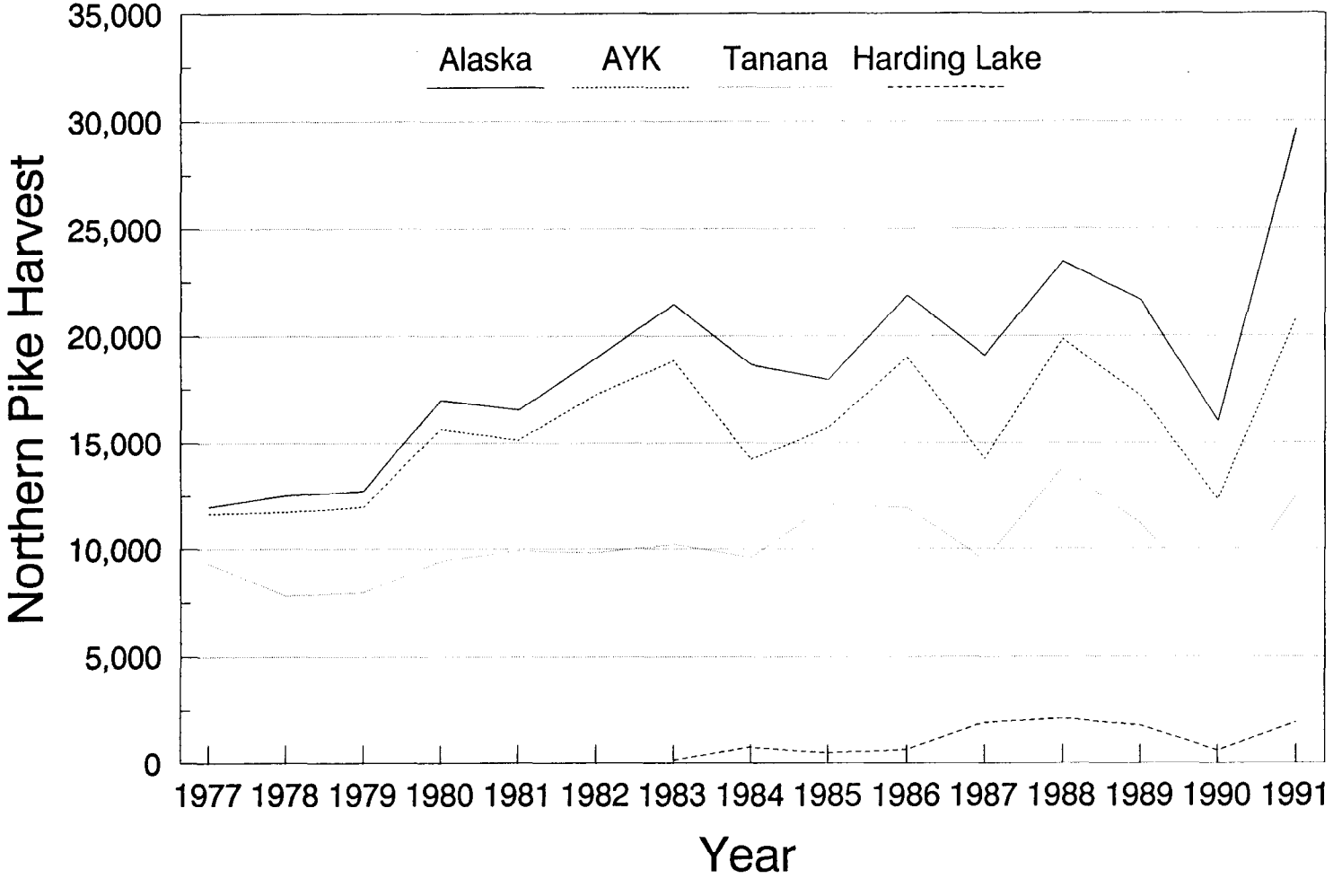

Figure 1. Harvest of northern pike in Alaska, Arctic-Yukon-Kuskokwim Region, Tanana drainage, and Harding Lake from 1977 through 1990 (Mills 1979-1991).

Table 1. Sport fishing effort and harvest of fish from Harding Lake, 1983 through 1992[a].

Year	Number of Anglers	Number of Trips	Number of Days Fished	Number of Fish Harvested[b]							
				LL	LT	AC	RT	GR	SF	NP	BB
1983			708	0	0	0	0	0	0	178	157
1984	436	1,219	1,707	65	0	0	0	0	0	766	428
1985	583	910	850	35	0	0	0	0	0	503	0
1986	1,590	1,758	2,064	0	24	0	0	0	0	673	0
1987	3,371	4,032	5,125	0	0	0	118	79	0	1,886	53
1988	2,599	3,806	3,256	0	55	0	73	0	73	2,092	73
1989	2,976	4,098	4,935	0	119	141	456	0	0	1,764	10
1990	2,650	3,410	3,895	0	51	304	354	17	0	591	17
1991	3,241	4,292	5,155	0	133	450	246	86	0	1,888	45

[a] Data sources: 1983, 1985, M.J. Mills, Alaska Department of Fish and Game, Anchorage, personal communication.
1984, 1986-1991, Mills (1985, 1987-1992).

[b] LL = Landlocked coho salmon, LT = lake trout, AC = Arctic char, RT = rainbow trout, GR = Arctic grayling, SF = sheefish, NP = northern pike, BB = burbot.

3. Northern pike less than 26 inches can not be possessed or retained; all northern pike less than 26 inches must be released immediately.

Data collected from this on-going study, along with estimates of sport harvest will provide information needed to evaluate these special regulations and assist ADF&G staff to insure the seasonal harvest does not exceed sustainable levels.

The objectives of this study in 1991 and 1992 were to:

1. Estimate the population abundance of northern pike; and,

2. Estimate the age and length compositions for the population of northern pike.

Study Area

Harding Lake is located 54 km (69 km by road) southeast of Fairbanks, near the confluence of the Salcha and Tanana rivers (Figure 2). The lake perimeter is circular except for a prominent point in the middle of the southern shoreline. Access to the lake is provided by three roads that exit the Richardson Highway on the lake's west side. One of the roads leads to a State campground. The other two connect with Salchacket Drive, which encircles approximately three-fourths of the shoreline. There is no road access to the north shore. Cabins and homes have been constructed along 75% of the shoreline. During summer, docks, rafts, and boat-lifts are in place in front of most cabins and homes. These structures are removed in the fall. There is a large State campground on the northwestern shoreline with a boat launch and channel to deep water, a swim beach, numerous campsites and parking areas, athletic fields, and some undeveloped areas for hiking and other outdoor recreation.

Surface elevation is 217 m, surface area is 1,000 ha, and maximum depth is 43 m. In addition to runoff, the lake is fed by springs, permafrost seeps, and two inlets. The East Inlet drains a 2,580 ha basin to the east of Harding Lake. The second inlet flows from adjacent Little Harding Lake. There is no outlet to the Salcha River, but flow into small areas of adjacent wetlands has been observed during high water periods. The littoral zone (the area from the shallows to the outer margins of the deep weed-beds of *Potamageton sp.* at 5 m) underlies 33% of the surface area of the lake.

Indigenous species include northern pike, burbot *Lota lota*, least cisco *Coregonus sardinella*, lake chub *Couesius plumbeus*, and slimy sculpin *Cottus cognatus*. Introduced species include lake trout *Salvelinus namaycush*, coho salmon *Oncorhynchus kisutch*, sockeye salmon *Oncorhynchus nerka*, rainbow trout, inconnu *Stenodus leucichthys*, Arctic char, and Arctic grayling.

Incidental information was collected on northern pike during the course of evaluations and assessments through the years, but no major study that specifically targeted the northern pike population occurred prior to 1990. Abundance, length and age compositions, and mean length-at-age of northern pike 450 mm and larger was estimated in 1990. Data were also collected from

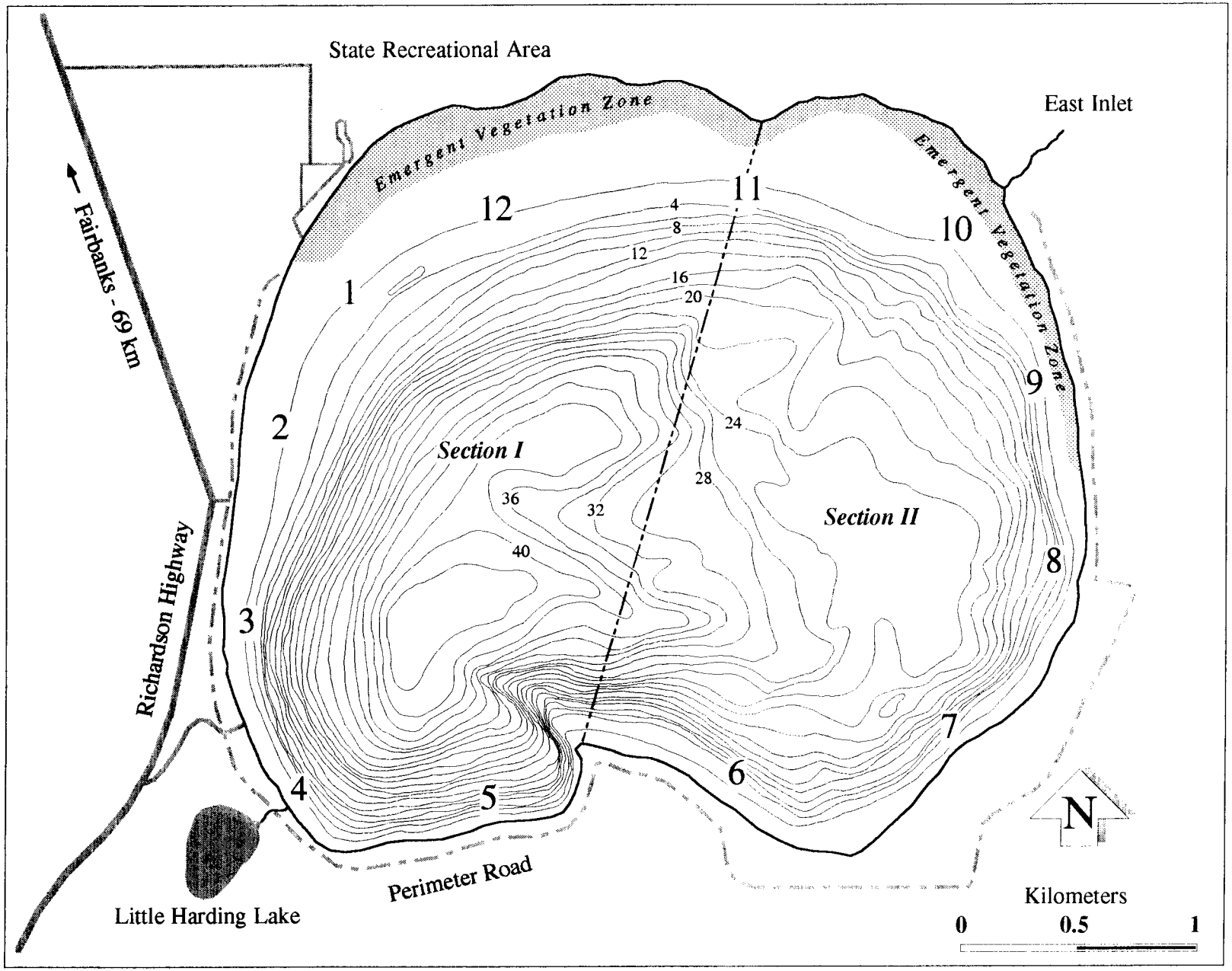

Figure 2. Harding Lake study area.

northern pike captured during studies of other species. Distribution, food preferences, and some length composition and length-at-age information has been compiled and included in various ADF&G reports. The largest documented northern pike from Harding Lake was a 1,140 mm, 13.62 kg (34.6 lb) female captured in a gill net in 1976. However, few northern pike over 5 kg have been documented during ADF&G studies or have been caught by anglers.

METHODS

The abundance of northern pike (300 mm and longer) in Harding Lake was estimated using intra-seasonal two-sample mark-recapture experiments in 1991 and again in 1992. Data from these experiments and data from a similar experiment conducted in 1990 (Burkholder 1991) also were used to estimate abundance by treating the data from each year as one event from an inter-seasonal two-sample mark-recapture experiment.

Intra-Seasonal Mark-Recapture Experiments

During the first event, a sample of the population was captured, marked, and released back into the population. During the second event, after allowing a short period for the marked and unmarked fish to mix, another sample was collected and examined for marks. All unmarked northern pike captured during the second events were marked. All captured northern pike were released back into the population.

1991:

Northern pike were captured in the spring after the ice had melted. The experiment was scheduled in the spring because at that time, northern pike concentrate in shallow water for spawning. In past years, the catch-per-unit-effort (CPUE) was highest in other lakes during spawning (Peckham and Bernard 1987; Clark 1988). In 1991, the first event was from 28 May through 31 May and the second event was from 3 June through 7 June. During both events, northern pike were captured with variable mesh gill nets using two methods. In the first method, gill nets were set offshore but perpendicular to the shoreline in water from 1 to 15 m deep. Twelve gill nets were used for four days in the first event and 22 gill nets were used for five days in the second event. To distribute sampling effort and facilitate statistical tests, the lake was divided arbitrarily into two sections (Figure 2). During both events one-half of the nets were used in each of the two sections and were roughly equally spaced around the lake perimeter. Roughly equal amounts of shoreline were surveyed in both sections during both events. About three days were spent in Section I and one day was spent in Section II during the first event. About 2.5 days were spent in each section during the second event. In the second method, two gill nets were set inshore in shallow water (less than 1 m deep), perpendicular to the shoreline, and 10 to 15 m apart. One person with a backpack mounted electro-fishing unit walked between the nets and "herded" fish into the nets. Data were recorded by section and capture gear.

During both events all captured northern pike were examined for fin clips and tags, measured from tip-of-snout to fork-of-tail to the nearest millimeter,

and scales were collected. Three scales were taken from the area above and adjacent to the lateral line and above the pelvic fins (Williams 1955). All northern pike were marked with a left or right pectoral fin clip and northern pike 300 mm and larger were also marked with a uniquely numbered blue internal anchor tag (Floy FD-68). During Event 1, northern pike captured in Section I were marked with a right pectoral fin clip and northern pike captured in Section II were marked with a left pectoral fin clip. Fins were clipped by removing the outer 1/4 of the fin with scissors. During Event 2, northern pike captured in Section I were marked with a right ventral fin clip and northern pike captured in Section II were marked with a left ventral fin clip. The tag was inserted at the base of the dorsal fin on the left side. When possible, sex was determined from shape of the vent or presence of milt or eggs.

1992:

In 1992, the first event was from 26 May through 29 May, 3 through 5 June, and 8 through 9 June. The second event was from 15 through 18 June. Methods used in 1992 were similar to those used in 1991 except 12 gill nets were used in both the first and second events and the gill nets were equally spaced around the lake perimeter in 1 to 15 m of water. Each gill net was fished at the same location during both events. However, from 26 May through 5 June, during the first event, gill nets were not used around the lake perimeter because of ice cover over water deeper than 1 m. During electro-fishing, three gill nets were set parallel to the shoreline instead of perpendicular. The locations of gill nets and all captured northern pike were marked on a map. The 12 equally spaced gill nets set around the lake perimeter served to define locations and areas. Each gill net was a location and an area was defined as the section between the mid-points between adjacent gill nets. Data were later stratified into two lake sections as was the data for the experiment in 1991. However, the division between sections in 1992 was different from that for 1991. Northern pike captured in Event 1 with electro-fishing gear were marked by punching the right pectoral fin and northern pike captured in gill nets were marked by punching the left pectoral fin. Northern pike captured in Event 2 with electro-fishing gear were marked by punching the upper lobe of the caudal fin and northern pike captured in gill nets were marked by punching the lower lobe of the caudal fin. All northern pike 300 mm and larger were also marked with a uniquely numbered yellow internal anchor tag (Floy FD-68).

Tests for Size Selectivity

Size-selectivity by gill nets (potential gear bias) was evaluated using two tests. Length distributions were compared for: 1) northern pike captured in the first event and marked northern pike recovered in the second event; and, 2) all northern pike captured in the first event and all northern pike captured in the second event. The Kolmogorov-Smirnov (K-S) statistic was used to test the null hypothesis of no difference between length frequency distributions. The procedures for detecting and adjusting for size-selectivity are listed in Appendix A.

Tests of Assumptions for Abundance Estimator

For a two-sample "Petersen" mark-recapture experiment, assumptions for an unbiased estimator are: a closed population during the experiment (no recruitment through growth or immigration) and no loss of marks; and complete mixing of tagged and untagged fish or equal probability of capture for all individuals during either the first event (marking) or the second event (recapture). The mark-recapture experiment was designed to insure against failure of these assumptions and, where possible, statistical tests were conducted to determine if an assumption failed.

Closed Population:

The population was closed to recruitment because the short time between sampling events (two days) minimized recruitment through growth. The absence of an outlet stream and the fish control structure at the inlet from Little Harding Lake eliminated recruitment through immigration.

Loss of Marks:

Clipped and punched fins could not grow back during the short period of the intra-seasonal experiments. Because a double mark was used, the rate of tag loss of Floy tags during the intra-seasonal experiments was estimated. The rate of loss of Floy tags from 1990 to 1991 to 1992 was not estimated because clipped fins often grew back a year after marking.

Probability of Capture:

Equal probabilities of capture by section were evaluated with a contingency table constructed of numbers of marked and unmarked northern pike captured in Event 2. A chi-square statistic was used to test the null hypothesis of no difference between rates of capture. With a two-event mark-recapture experiment, equal probabilities of capture can be tested only for the first event. Equal probabilities of capture during the second event can only be inferred from specifics of the first and second capture events and comparisons of stratified and unstratified estimates of abundance.

Mixing:

Mixing between sections was evaluated through inspection of the capture history. A matrix was made of numbers of marked northern pike that were marked during Event 1 by lake section and later recovered during Event 2 by lake section. The off-diagonals of the matrix indicated if mixing occurred.

Abundance Estimator

Stratified and unstratified estimates of abundance of northern pike 300 mm FL and longer were estimated using a modified Petersen mark-recapture estimator (Chapman 1951). The approximate variance of this estimate is from Seber (1982).

$$\hat{N} = \frac{(C+1)(M+1)}{(R+1)} - 1; \text{ and,} \quad (1)$$

$$\hat{V}[N] = \frac{\hat{N}(C-R)(M-R)}{(R+1)(R+2)}; \quad (2)$$

where:

C = number of fish captured during Event 2;
M = number of fish marked and released alive during Event 1; and,
R = number of marked fish recaptured during Event 2.

When data were stratified, abundance was estimated for each strata and then added for a total estimate of abundance.

Length Composition

Annual estimates of abundance of the northern pike population were apportioned into the following size categories:

1. Length frequency intervals of 25 mm starting at 300 mm;

2. "Small" (300-449 mm), "Medium" (450-749 mm), "Large" (750 mm and larger), and "All northern pike 450 mm and longer"; and,

3. Relative Stock Densities (RSD; Gabelhouse 1984) in "stock" (300-524 mm), "quality" (525-624 mm), "preferred" (655-859 mm), "memorable" (860-1,079 mm), and "trophy" (larger than 1,079 mm).

Lengths from the second events of the mark-recapture experiments were used to estimate proportions in the population for 1991 and 1992. In addition, the estimate of abundance and length data from the second event during the mark-recapture experiment in 1990 were used to apportion the northern pike population in 1990 into these same length categories for fish 450 mm and larger.

Estimates of length compositions were calculated as follows:

$$p_{ij} = n_{ij}/n_i \quad (3)$$

where:

n_i = the number sampled from stratum i in the mark-recapture experiment;
n_{ij} = the number sampled from stratum i that belong to group j; and,
p_{ij} = the estimated fraction of the fish in group j in stratum i.

Note that $\sum_j p_{ij} = 1$. The variance for p_{ij} is:

$$V[p_{ij}] = \frac{p_{ij}(1 - p_{ij})}{n_i - 1} \quad (4)$$

The estimated abundance of group j in the population (N_j) is:

$$N_j = \sum_i p_{ij} N_i \quad (5)$$

where N_i = the estimated abundance in stratum i of the mark-recapture experiment. The variance for N_j is a sum of the exact variance of a product from Goodman (1960):

$$V[N_j] = \sum_i (V[p_{ij}]N_i^2 + V[N_i]p_{ij}^2 - V[p_{ij}]V[N_i]) \quad (6)$$

The estimated fraction of the population that belongs to group j (p_j) is:

$$p_j = N_j/N \quad (7)$$

where $N = \sum R N_i$. The variance of the estimated fraction can be approximated with the delta method (*see* Seber 1982):

$$V[p_j] \approx \sum_i V[p_{ij}] \left\{ \frac{N_i}{N} \right\}^2 + \frac{\sum V[N_i] (p_{ij} - p_j)^2}{N^2} \quad (8)$$

Growth

In May and June 1990, northern pike were captured, measured, and tagged during a mark-recapture experiment (Burkholder 1991). Some of these fish were captured again during a second mark-recapture experiment in May and June 1991. Some of the fish captured in 1991 were captured again during a third mark-recapture experiment in May and June 1992. All unmarked fish captured during these mark-recapture experiments were given marks. Fish recaptured in 1992 included fish marked in 1990 and recaptured in 1991 and fish marked in 1991. For these recaptured fish, annual growth in length was calculated using the following formula:

$$G = L_i - L_f \quad (9)$$

where:

G = annual increment of growth (mm);
L_i = initial length; and,
L_f = final length.

Mean growth by 50 mm length intervals for northern pike 300 mm and longer was estimated for each interval using the mean and sample variance for simple random sampling.

Age Composition

Methods to estimate age composition were the same as those used to estimate length composition. Ages were determined by counting annuli on scales collected during the mark-recapture experiments. Impressions of scales were made into 20 mil acetate sheets using a Carver press at 137,895 kPa (20,000 psi) heated to 93 C for one minute. Scales were read on a microfiche reader (32x) and ages recorded in accordance with criteria for recognizing annuli established by Williams (1955), Frost and Kipling (1959), and Casselman (1978).

Error in Age Determination

Ages were compared for northern pike recaptured in 1991 and 1992. The error in age determination for each fish was calculated as:

$$\text{Error} = (AGE_0 + 1) - AGE_1 \quad (10)$$

where:

Error = error in age determination;
AGE_0 = age when first captured in 1990 or 1991; and,
AGE_1 = age when recaptured the following year.

Mean Length at Age

Length data for northern pike 300 mm and longer collected during the mark-recapture experiments were separated by age. Mean lengths for each age were then estimated using the mean and sample variance for simple random sampling. Estimates were made for 1990, 1991, and 1992.

Rates of Survival and Recruitment

Rates of survival and recruitment were estimated using a triple-catch mark-recapture experiment (Bailey 1951; and discussed by Ricker 1975). Data sets were from the intra-seasonal two-event mark-recapture experiments conducted in 1990, 1991, and 1992.

Bailey's small-sample formulae (using Ricker's notation) for direct estimates of survival rates and recruitment are:

$$S_{12} = \frac{M2R_{13}}{(R_{12}+1)(R_{23}+1)} \quad (11)$$

$$V(S_{12}) = S^2_{12} - \frac{M^2{}_2R_{13}(R_{13}-1)}{M^2{}_1(R_{23}+1)(R_{23}+2)} \quad (12)$$

$$r_{23} = \frac{R_{12}(C_3+1)}{C_2(R_{12}+1)} \quad (13)$$

$$V(r_{23}) = r^2_{23} - \frac{R_{12}(R_{12}-1)C_3(C_3+2)}{C_2(C_2-1)(R_{13}+1)(R_{13}+2)} \quad (14)$$

where:

M_1 = number of fish newly marked in 1990;
M_2 = number of fish newly marked in 1991;
C_2 = number of fish examined for marks in 1991;
C_3 = number of fish examined for marks in 1992;
R_{12} = number of fish recaptured in 1991 that were marked in 1990;
R_{13} = number of fish recaptured in 1992 that were marked in 1990;
R_{23} = number of fish recaptured in 1992 that were marked in 1991;
S_{12} = rate of survival from 1990 to 1992;
$V(S_{12})$ = variance of S_{12};
r_{23} = rate of recruitment from 1991 to 1992; and,
$V(r_{23})$ = variance of r_{23}.

The instantaneous rate of mortality (Z) was estimated using:

$$Z_{12} = -\ln(S_{12}) \quad (15)$$

where:

Z_{12} = the instantaneous rate of mortality from 1990 to 1991.

Inter-Seasonal Mark-Recapture Experiments

Inter-seasonal estimates of abundance were made using data from intra-seasonal experiments conducted in 1990, 1991, and 1992. Data obtained in 1990 and 1991 were used to estimate the abundance of northern pike in 1990 and data obtained in 1991 and 1992 were used to estimate the abundance of northern pike in 1991. These data were treated as having come from a two-sample Petersen type mark-recapture experiment. For the estimate of abundance germane to 1990, the marking event was considered to have occurred in 1990 and the recapture event occurred in 1991. For the estimate of abundance germane to 1991, the marking event was considered to have occurred in 1991 and the recapture event occurred in 1992.

Evaluation of the data sets for length-selectivity was not appropriate because of annual growth. However, cumulative length frequency distributions were used to examine growth and compare the distributions of the samples. The

estimate of abundance was stratified by length (300 mm to <500 mm and ≥500 mm in Event 1 and 443 mm to <597 mm and ≥597 in 1992. Recruitment through growth was eliminated by length isolation. Elimination of recruitment by age isolation was not used due to the inaccuracy of determining age from scales of northern pike in Harding Lake (This report and Pearse and Hansen 1992). Mean growth of northern pike marked in 1990 or 1991 (Event 1) and recaptured one year later (Event 2) was evaluated by 50 mm intervals for fish equal to 300 mm and longer. Mean growth of northern pike with an initial size of 300 to 349 mm during Event 1 was 143 mm. Consequently, northern pike captured during Event 2 less than 443 mm were considered recruitment and were not used to estimate abundance.

Assumptions for a two-sample Petersen estimator (probability of capture and mixing) could not be evaluated because lake sections were different in 1990, 1991, and 1992.

Location and Movement of Northern Pike in 1992

Locations of northern pike recaptured during both events were marked on a map to monitor movement during the mark-recapture experiment. From 26 May to 29 May 1992 (Event 1), radio tags were surgically inserted into 26 northern pike as part of another study. The capture location and sex of these northern pike were also recorded.

RESULTS

1991

During the first event, 127 northern pike were captured, marked, and released. During the second event, 325 northern pike were captured and examined for marks. Of these fish, 19 were recaptured from the first event. The following results were used to select an appropriate abundance estimator and to determine appropriate methods for estimating length compositions. No mortality of northern pike incidental to sampling occurred.

Tests for Size-Selectivity:

Length distributions of northern pike captured in Event 1 and recaptured in Event 2 were not different ($P = 0.48$, $DN = 0.21$, $n_{Event1} = 127$, $n_{Recaptured} = 19$; Figure 3, 1991a). Length distributions of northern pike captured in Event 1 and Event 2 also were not different ($P = 0.06$, $DN = 0.14$, $n_{Event1} = 127$, $n_{Event2} = 325$; Figure 3, 1991b). These tests indicated that there was no size-selectivity during either the first or second events. However, examination of the distributions indicated that there was some size-selectivity in both events. In Figure 3, 1991a the DN is large; but due to the small sample size (19 recaptured northern pike) the power of the test was too low to certify that the difference was significant. In Figure 3, 1991b the DN was not as large but the P value was quite small. The small P value is probably due to a small but biologically insignificant difference between the samples and the high power of the test (due to the large sample sizes) to detect a small difference. The conservative approach was to reject both

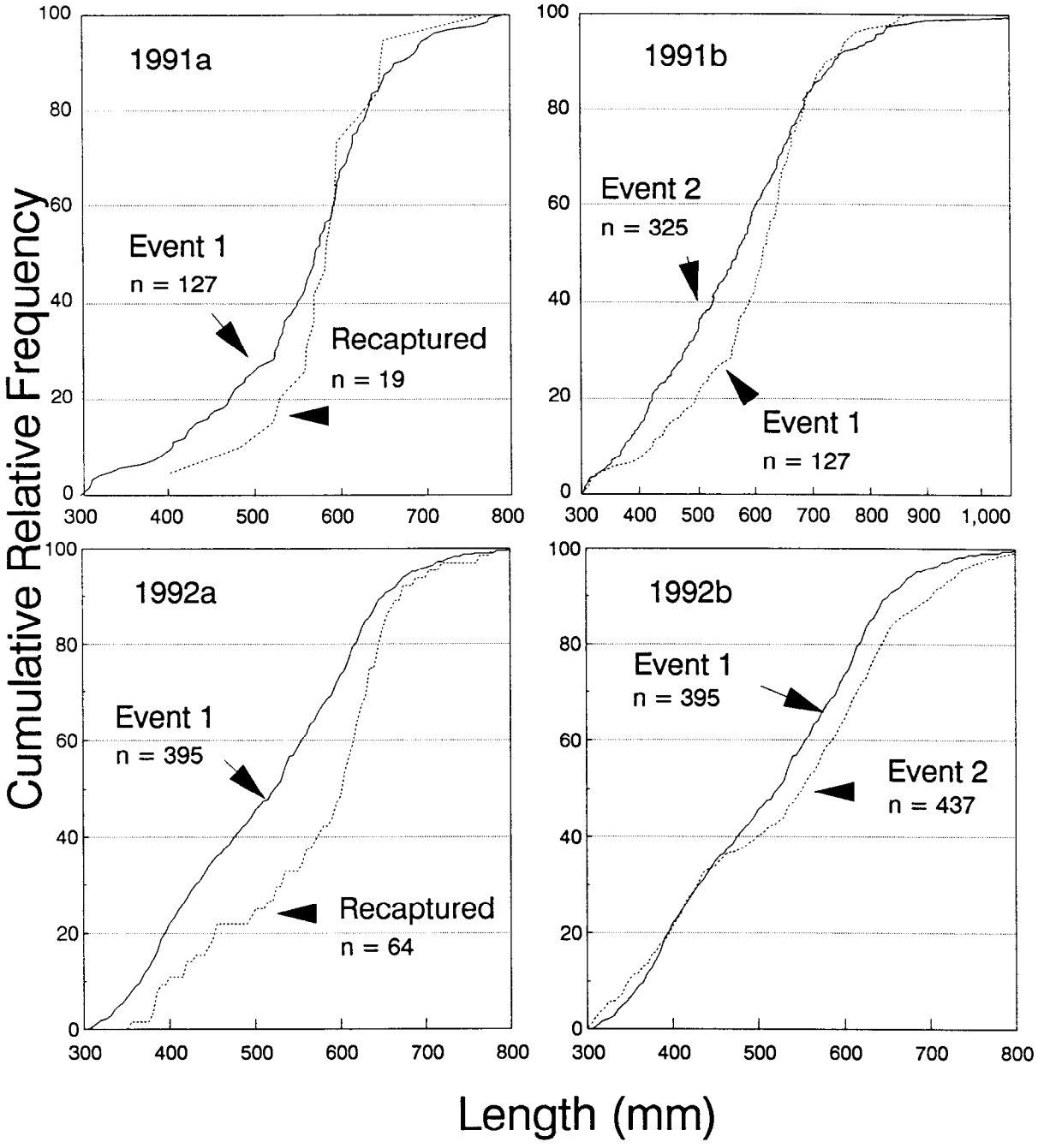

Figure 3. Cumulative relative frequency of northern pike captured in Event 1, Event 2, and marked northern pike recaptured in Event 2, 1991 and 1992.

hypothesis and completely stratify both sampling events and estimate abundance for each stratum. The sum of these estimates of abundance were then compared to an estimate of abundance without stratification to evaluate the bias.

Tests of Assumptions for Unstratified Abundance Estimator:

During Event 1, 121 northern pike were marked in Section I and six were marked in Section II (Tables 2 and 3). During Event 2, 123 northern pike were captured in Section I (16 marked and 107 unmarked) and 202 northern pike were captured in Section II (three marked and 199 unmarked; Tables 2 and 3). All 19 marked fish were originally captured and released in Section I during Event 1. None of the six northern pike captured and released in Section II during Event 1 were captured in Event 2 (Table 4).

Probability of Capture. Rates of recapture of marked northern pike in Sections I and II were 0.13 and 0.02 and were different ($P < 0.0001$, $\chi^2 = 18.4$, DF = 1; Table 3).

Mixing. Examination of the capture history of marked northern pike showed some movement of northern pike from Section I to Section II (Table 4). The status of mixing from Section II to Section I is not known because too few northern pike were captured during the first event in Section II.

Because the experimental design assured a closed population and no loss of marks, for the abundance estimator to be valid either the probabilities of capture must be equal or mixing must occur. These tests indicated the estimator might be biased because the probabilities of capture during the first event were different in Sections I and II. This difference was because too few northern pike were captured in Section II during Event 1. Catch statistics (Table 2) indicated that catches were probably related to local abundance and not different probabilities of capture (Table 3). Too few northern pike were marked in Section II because it is likely that only a small proportion of the population was present in Section II during Event 1.

Abundance Estimate:

After considering the results from the above tests, the data were stratified by length category (Table 5). The stratified estimates of abundance of northern pike 300 mm to less than 550 mm was 1,543 (SE = 539) and of northern pike 550 mm and larger was 765 (SE = 163; Table 6). The combined estimate of abundance was 2,308 (SE = 563). The unstratified estimate of abundance of northern pike 300 mm and larger was 2,086 (SE = 405; Table 6).

1992

During the first event, 395 northern pike were captured, marked, and released. During the second event, 437 northern pike were captured and examined for marks. Of these fish, 64 were marked. The numbers used in the following tests are slightly different from the actual catches because in some instances fish were captured but not measured or scales were not collected. No mortality of northern pike incidental to sampling occurred.

Table 2. Catch statistics for northern pike captured by event, lake section, capture gear, and effort in 1991.

	Section I Catch (Effort)		Section II Catch (Effort)		Totals
Event 1:					
EF[a]	78	(3 days)	2	(1 days)	80
GN[b]	43	(6 gillnets, 4 days)	4	(6 gillnets, 4 days)	47
Totals	121		6		127
Event 2:					
EF[a]	31	(2.5 days)	101	(2.5) days	132
GN[b]	92	(11 gillnets, 5 days)	101	(11 gillnets, 5 days)	193
Totals	123		202		325
Grand Totals	244		208		452

[a] Method of capture was electro-fishing.
[b] Gillnets were used to capture northern pike.

Table 3. Number of marked and unmarked northern pike captured in Event 2 by lake section, 1991.

	Lake Section		
	I	II	Total
Marked	16	3	19
Unmarked	107	199	306
Total collected	123	202	325
Recovery rate	0.13	0.02	0.06

$\chi^2 = 18.4$
DF = 1
$P < 0.0001$

Table 4. Capture history of northern pike by lake section, 1991.

Event 1	Event 2		Not Recovered	Total
	Section I	Section II		
Section I	16	3	102	121
Section II	0	0	6	6
Total released	16	3	108	127

Table 5. Summary of the number of northern pike from intra- and inter-seasonal two-event mark-recapture experiments, 1990 through 1992.

Experiment Date	Event	Number	Length Categories (mm FL)	Number	Length Categories (mm FL)
1990					
14-25 May 1990	Event 1[a]	346	≥ 450 mm		
29-31 May 1990	Event 2[b]	184	≥ 450 mm		
	Marked[c]	49			
1990-91					
14 May - 31 May 1990	Event 1	169	300 to < 500 mm	383	≥ 500 mm
28 May - 7 Jun 1991	Event 2	203	443 to < 597 mm	128	≥ 597 mm
	Marked	21		69	
1991					
28 - 31 May 1991	Event 1	51	300 to < 550 mm	76	≥ 550 mm
3 - 7 Jun 1991	Event 2	177	300 to < 550 mm	148	≥ 550 mm
	Marked	5		14	
1991-92					
28 May - 7 Jun 1991	Event 1		300 to < 500 mm		≥ 500 mm
26 May - 18 Jun 1992	Event 2		443 to < 597 mm		≥ 597 mm
	Marked				
1992					
26 May - 9 Jun 1992	Event 1	233	300 to < 550 mm	162	≥ 550 mm
15 - 18 Jun 1992	Event 2	218	300 to < 550 mm	219	≥ 550 mm
	Marked	25		39	

[a] All northern pike captured, marked, and then released in Event 1.
[b] All marked and unmarked northern pike captured in Event 2.
[c] All marked northern pike captured in Event 2.

Table 6. Abundance and density of various size groups of northern pike in Harding Lake, 1990 - 1992.

	Small (300-449 mm)				Medium (450-749 mm)				Large (Larger than 749 mm)				All (Larger than 299 mm)			All (Larger than 449 mm)			
	Abundance		Proportion		Abundance		Proportion		Abundance		Proportion		Abundance		Density	Abundance		Proportion		Density
Year	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	(Fish/Ha)	Estimate	SE	Estimate	SE	(Fish/Ha)
1990[a]					1,246	(141)	0.97	(0.014)	37	(11)	0.03	(0.014)				1,283	(145)			1.3
1990/91[b]	827	(164)	0.36	(0.034)	1,442	(159)	0.63	(0.034)	16	(6)	0.01	(0.002)	2,284	(294)	2.3	1,458	(159)	0.64	(0.034)	
[c]													2,017	(164)	2.0					
1991[b]	487	(103)	0.23	(0.020)	1,530	(300)	0.73	(0.021)	68	(22)	0.03	(0.008)	2,086	(405)	2.1	1,599	(311)	0.76	(0.056)	1.6
[c]	781	(279)	0.34	(0.048)	1,472	(312)	0.64	(0.048)	54	(20)	0.02	(0.008)	2,308	(563)	2.3	1,527	(313)	0.66	(0.049)	1.5
1991/92[b]	738	(104)	0.38	(0.031)	1,144	(88)	0.60	(0.032)	42	(11)	0.02	(0.006)	1,923	(155)	1.9	1,175	(88)	0.61	(0.032)	1.2
[c]													1,865	(129)	1.9					
1992[b]	1,372	(242)	0.48	(0.034)	1,430	(159)	0.50	(0.037)	66	(19)	0.02	(0.006)	2,868	(353)	2.9	1,496	(160)	0.52	(0.038)	1.5
[c]	913	(105)	0.34	(0.017)	1,690	(181)	0.63	(0.017)	65	(16)	0.02	(0.005)	2,667	(277)	2.7	1,755	(182)	0.66	(0.018)	1.8

[a] Abundance was estimated only for northern pike ≥ 450 mm in 1990.
[b] Stratified
[c] Unstratified

Tests for Size Selectivity:

Length distributions of northern pike captured in Event 1 and recaptured in Event 2 were different ($P = 0.0001$, $DN = 0.31$, $n_{Event1} = 390$, $n_{Recaptured} = 64$; Figure 3, 1992a). Length distributions of northern pike captured in Event 1 and Event 2 also were different ($P = 0.003$, $DN = 0.13$, $n_{Event1} = 390$, $n_{Event2} = 434$; Figure 3, 1992b). These tests indicated that there was size selectivity during the second event; the status of size-selectivity during the first event is unknown. The conservative approach was to reject both hypothesis and completely stratify both sampling events and estimate abundance for each stratum. The sum of these estimates of abundance were then compared to an estimate of abundance without stratification to evaluate the bias.

Tests of Assumptions for Abundance Estimator:

Probability of capture. There was no difference between the probabilities of capture for the 12 areas defined by gill net locations ($P = 0.075$, Table 7). When the lake was divided into two sections, there was no difference between the probabilities of capture by section ($P = 0.21$, Table 8). Areas 2-9 comprise Section I and areas 10-12 and 1 comprise Section II.

Mixing. Examination of the off-diagonals of the capture-recapture history of northern pike indicated there was some mixing of northern pike between sections (Tables 9 and 10).

Abundance Estimate:

After considering the results from the above tests, the data were stratified by length category (Table 5). The estimated abundance of northern pike 300 mm to 550 mm was 897 (SE = 110) and northern pike larger than 550 mm was 1,971 (SE = 336; Table 6). The combined estimated abundance of northern pike 300 mm and longer was 2,868 (SE = 353). The unstratified estimate of abundance of northern pike 300 mm and larger was 2,667 (SE = 277; Table 6).

1990-1991

In 1990 (Event 1), 570 northern pike were captured, marked, and released. In 1991 (Event 2), 432 northern pike were captured and examined for marks. Of these fish, 93 were marked. The data sets were edited by removing fish that did not meet criteria for length and growth (Table 5). Length was not measured for five fish captured during Event 1; but, the length strata for these fish for Event 1 was inferred from the length when captured in Event 2 and the mean growth of similar size fish. Twenty-three fish from the first event did not meet the growth criteria. For three of the 93 recaptured fish lengths were less during Event 2 than during Event 1. In the 1991 data set, lengths were not measured for seven fish and 94 fish were considered recruits (less than 443 mm).

Table 7. Number of marked and unmarked northern pike captured in Event 2 by area, 1992.

Area	Marked	Unmarked	Total
1	2	22	24
2	1	5	6
3	0	0	0
4	2	28	30
5	3	29	32
6	1	4	5
7	0	0	0
8	0	0	0
9	6	31	37
10	18	43	61
11	20	126	146
12	11	78	89
Total	64	366	430

Note: areas 3, 7, and 8 are not included in analysis.
$\chi^2 = 14.3$
DF = 8
P = 0.075

Table 8. Number of marked and unmarked northern pike captured in Event 2 by lake section, 1992.

	Lake Section		
	I(2-9)	II(10-12,1)	Total
Marked	13	51	64
Unmarked	104	269	373
Total collected	117	320	437
Recovery rate	0.11	0.18	0.06

$\chi^2 = 1.6$
DF = 1
P = 0.21

Table 9. Capture history of northern pike by area, 1992.

	Event 2													
Event 1	1	2	3	4	5	6	7	8	9	10	11	12	Not Recaptured	Total
1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	1	0	4	5
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	4	4
9	0	0	0	1	1	0	0	0	1	1	0	0	13	17
10	0	0	0	0	2	0	0	0	4	7	0	0	59	72
11	0	0	0	1	0	0	0	0	0	3	0	1	40	45
12	2	1	0	0	0	1	0	0	1	7	18	10	210	250
Total	2	1	0	2	3	1	0	0	6	18	19	11	332	395

Table 10. Capture history of northern pike by lake section, 1992.

Event 1	Event 2		Not Recovered	Total
	Section I	Section II		
Section I	3	2	22	27
Section II	10	48	310	368
Total released	13	50	332	395

Comparison of Cumulative Length Distributions:

Cumulative length distributions of northern pike captured in Event 1 and recaptured in Event 2 showed growth (Figure 4, 1990-1991a). Length distributions of northern pike captured in Event 1 and Event 2 were similar for large fish (≥500 mm) but dissimilar for small fish (<500 mm; Figure 4, 1990-1991b). Smaller northern pike comprised a greater portion of the sample in 1991 than in 1990.

Abundance Estimate:

The conservative approach was to completely stratify both sampling events by length category (Table 5) and estimate abundance for each stratum. The sum of these estimates of abundance were then compared to an estimate of abundance without stratification to evaluate any potential bias. The stratified estimates of abundance of northern pike 300 mm to less than 500 mm was 1,576 (SE = 290) and 500 mm and longer was 708 (SE = 51; Table 6). The combined estimate of abundance was 2,284 (SE = 294). The unstratified estimate of abundance of northern pike 300 mm and larger was 2,017 (SE = 164; Table 6).

1991-1992

In 1991 (Event 1), 432 northern pike were captured, marked, and released. In 1992 (Event 2), 760 northern pike were captured and examined for marks. Of these fish, 117 were marked. The data sets were edited by removing fish that did not meet criteria for length and growth when conducting some of the statistical tests. The length was not measured for seven fish captured during Event 1; but, the length strata for these fish for Event 1 was inferred from the length when captured in Event 2 and the mean growth of similar size fish. The length of two of the 117 recaptured fish was less during Event 2 than during Event 1. In the 1992 data set, 260 northern pike were considered recruits (less than 443 mm). The following results were used to select an appropriate abundance estimator.

Comparison of Cumulative Length Distributions:

Cumulative length distributions of northern pike captured in Event 1 and recaptured in Event 2 showed growth (Figure 4, 1991-1992a). Length distributions of northern pike captured in Event 1 and Event 2 were similar for large fish (≥550 mm) and dissimilar for small fish (<550 mm; Figure 4, 1990-1991b). Smaller northern pike comprised a greater portion of the sample in 1992 than in 1991.

Abundance Estimate:

The conservative approach was to completely stratify both sampling events by length category (Table 5) and estimate abundance for each stratum. The sum of these estimates of abundance were then compared to an estimate of abundance without stratification to evaluate any potential bias. The stratified estimates of abundance of northern pike 300 mm to less than 500 mm was 1,099 (SE = 142) and 500 mm and longer was 824 (SE = 63). The combined estimate of

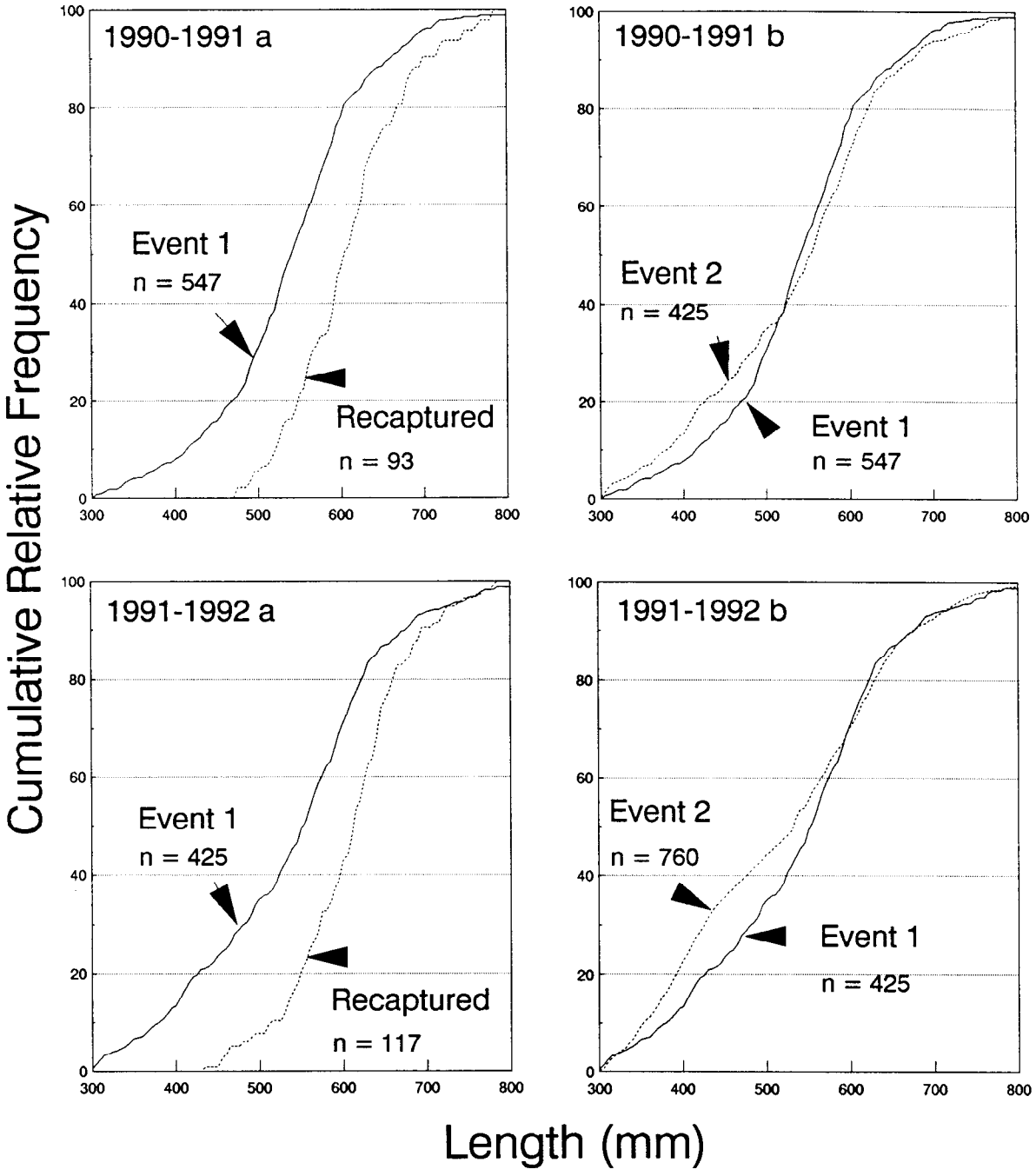

Figure 4. Cumulative relative frequency of northern pike captured in Event 1, Event 2, and marked northern pike recaptured in Event 2, 1990-1991 and 1991-1992.

abundance was 1,913 (SE = 155; Table 6). The unstratified estimate of abundance of northern pike 300 mm and larger was 1,865 (SE = 129; Table 6).

Length Composition

In 1991, lengths were obtained for 472 individual northern pike during Events 1 and 2. Lengths ranged from 159 mm to 964 mm (Figure 5; Table 11). There were 428 northern pike 300 mm and larger and 328 northern pike 450 mm and larger in samples collected during both events in 1991. In 1992, lengths were obtained for 802 individual northern pike during Events 1 and 2. Lengths ranged from 153 mm to 882 mm (Figure 5; Table 11). There were 760 northern pike 300 mm and larger and 490 northern pike 450 mm and larger in samples collected during both events in 1992. For comparison, in 1990, lengths were obtained for 596 individual northern pike during Events 1 and 2 (Burkholder 1991). Lengths ranged from 113 mm to 847 mm (Figure 5; Table 11). There were 568 northern pike 300 mm and longer and 475 northern pike 450 mm and longer.

Only northern pike captured during the second event (intra-seasonal data set) were used to apportion the estimates of abundance by length categories based on the results of the statistical tests. When abundance was apportioned into 25 mm categories most northern pike were within 400 to 650 mm for 1991 and 300 to 425 mm for 1992 (Table 12).

When apportioned into small, medium, and large length categories, more than half of the northern pike were in the medium category (Table 6). To make comparisons between estimates of population abundance in 1990, 1991, and 1992, inter-seasonal stratified estimates were used for 1990 (1990-1991 data sets) and 1991 (1992-1992 data sets) and the intra-seasonal stratified estimate for 1992 (1992 data set). The abundance of northern pike in the medium and large categories has remained consistent from 1990 (1,144 medium and 16 large) to 1992 (1,442 medium and 66 large). However, the abundance of small northern pike increased from about 750 in 1990 and 1991 to 1,372 in 1992 (Table 6).

In 1991 and 1992, most of the population of northern pike 300 mm and longer were rated as stock (RSD = 57% and 60%) or quality (RSD = 34 and 29; Table 13). The RSDs in 1990, 1991, and 1992 were similar for northern pike 450 mm and longer (Table 13). In all years most of the population was rated quality (RSD = 64% in 1990, 61% in 1991, and 56% in 1992). Only one fish was rated memorable in 1991; no memorable fish were captured in either 1990 or 1992. No trophy northern pike were captured in 1990, 1991, or 1992.

Age Composition

For 1990 through 1992, northern pike captured ranged from age 2 to age 12 (Table 14). Although ages 4 through 7 comprised the largest proportion in the samples, the proportions for each age in the samples were variable between years.

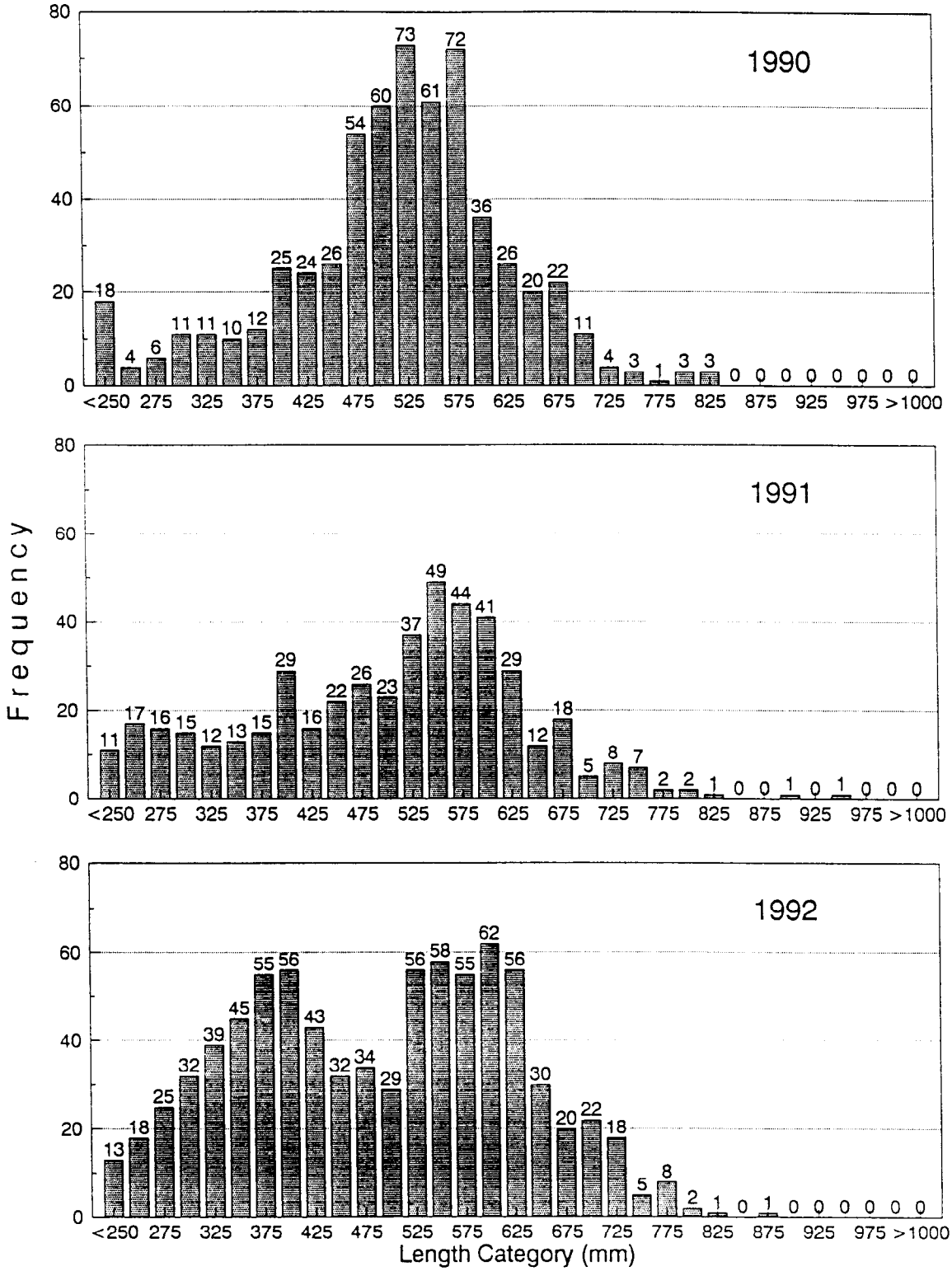

Figure 5. Histograms of lengths of all northern pike captured during mark-recapture experiments in Harding Lake, 1990-1992.

Table 11. Length frequency of all northern pike captured in Harding Lake during mark-recapture experiments, 1990-1992.

Length Class (mm)	1990		1991		1992	
	Number	Proportion	Number	Proportion	Number	Proportion
< - 249	18	0.030	11	0.023	13	0.016
250 - 274	4	0.006	17	0.036	18	0.022
275 - 299	6	0.010	16	0.033	25	0.031
300 - 324	11	0.018	15	0.031	32	0.040
325 - 349	11	0.018	12	0.025	39	0.049
350 - 374	10	0.016	13	0.027	45	0.056
375 - 399	12	0.020	15	0.031	55	0.069
400 - 424	25	0.041	29	0.061	56	0.070
425 - 449	24	0.040	16	0.033	43	0.054
450 - 474	26	0.043	22	0.046	32	0.040
475 - 499	54	0.090	26	0.055	34	0.042
500 - 524	60	0.100	23	0.048	29	0.036
525 - 549	73	0.122	37	0.078	56	0.070
550 - 574	61	0.102	49	0.103	58	0.072
575 - 599	72	0.120	44	0.093	55	0.069
600 - 624	36	0.060	41	0.086	62	0.077
625 - 649	26	0.043	29	0.061	56	0.070
650 - 674	20	0.033	12	0.025	30	0.037
675 - 699	22	0.036	18	0.038	20	0.025
700 - 724	11	0.018	5	0.010	22	0.027
725 - 749	4	0.006	8	0.016	18	0.022
750 - 774	3	0.005	7	0.014	5	0.006
775 - 799	1	0.001	2	0.004	8	0.010
800 - 824	3	0.005	2	0.004	2	0.002
825 - 849	3	0.005	1	0.002	1	0.001
850 - 874	0		0		0	
875 - 899	0		0		1	0.001
900 - 924	0		1	0.002		
925 - 949	0		0			
950 - 974	0		1	0.002		
975 - 999	0		0			
1,000 - 1,024	0		0			
> 1,024	0		0			
Total	596		472		802	

Table 12. Estimates of abundance apportioned by length class for the northern pike populations in Harding Lake 1990-1992.

Length Class (mm)	1990 Abundance	1990 SE	1991 Abundance	1991 SE	1992 Abundance	1992 SE
300 - 324			73	23	244	62
325 - 349			58	20	203	55
350 - 374			63	21	224	58
375 - 399			73	23	183	51
400 - 424			141	37	325	76
425 - 449			78	24	193	53
450 - 474	37	19	107	30	122	40
475 - 499	47	21	127	34	122	40
500 - 524	122	35	112	31	102	35
525 - 549	159	40	180	45	244	62
550 - 574	150	39	239	56	147	31
575 - 599	243	51	214	51	132	29
600 - 624	140	38	200	49	132	29
625 - 649	131	36	141	37	147	31
650 - 674	94	30	58	20	81	22
675 - 699	84	29	88	26	61	18
700 - 724	28	16	24	12	66	19
725 - 749	9	9	39	15	76	21
750 - 774	19	13	34	14	25	12
775 - 799	9	9	10	7	25	12
800 - 824	0		10	7	5	5
825 - 849	9	9	5	5	5	5
850 - 874	0		0		5	5
875 - 899	0		0			
900 - 924	0		5	5		
925 - 949	0		0			
950 - 974	0		5	5		
975 - 999	0		0			
1,000 - 1,024	0		0			
> 1,024	0		0			
Total	1,283		2,086		2,869	

Table 13. Percent Relative Stock Densities (RSD)[a] and abundance of northern pike in Harding Lake, 1990-1992.

Year	Gabelhouse[a] Minimum Length (mm)	RSD	Standard Error	Number of Fish: Estimated Abundance	Number of Fish: Standard Error
1990[b]: Length ≥ 450 mm.					
Stock	300	18	3	230	45
Quality	525	64	4	816	102
Preferred	655	18	3	237	45
Memorable	855				
Trophy	1,080				
Total		100		1,283	
1991: Length ≥ 450 mm.					
Stock	300	22	2	521	
Quality	525	61	3	787	152
Preferred	655	16	2	205	52
Memorable	855	1	<1	11	8
Trophy	1,080				
Total		100		1,524	
1991: Length ≥ 300 mm.					
Stock	300	57	7	1,305	458
Quality	525	34	6	787	152
Preferred	655	9	2	205	52
Memorable	855	<1	<1	11	8
Trophy	1,080				
Total		100		2,308	

-continued-

Table 13. (Page 2 of 2).

Year	Gabelhouse[a] Minimum Length (mm)	RSD	Standard Error	Number of Fish: Estimated Abundance	Number of Fish: Standard Error
1992: Length ≥ 450 mm.					
Stock	300	21	4	346	
Quality	525	56	4	831	101
Preferred	655	22	3	314	50
Memorable	855	<1	<1	5	5
Trophy	1,080				
Total		100		1,496	
1992: Length ≥ 300 mm.					
Stock	300	60	4	1,717	296
Quality	525	29	3	831	101
Preferred	655	11	2	314	50
Memorable	855	<1	<1	5	5
Trophy	1,080				
Total		100		2,867	

[a] Relative Stock Density (RSD) expressed as a percentage; categories taken from Gabelhouse (1984).

[b] Data from Burkholder (1991).

Table 14. Age composition of the northern pike population in Harding Lake, 1990-1992.

Age	Sample Size	Proportion P	Proportion (SE)	Abundance N	Abundance (SE)	Mean Length L	Mean Length (SE)
1990[a]							
2	1	0.01	(0.005)	11	(11)	305	
3	15	0.07	(0.018)	160	(48)	330	(8)
4	47	0.21	(0.029)	484	(106)	407	(6)
5	88	0.29	(0.030)	657	(125)	487	(5)
6	149	0.26	(0.026)	594	(86)	536	(3)
7	112	0.11	(0.010)	242	(26)	594	(3)
8	43	0.04	(0.006)	93	(15)	668	(6)
9	16	0.02	(0.004)	35	(9)	700	(14)
10	4	<0.01	(0.002)	9	(4)	831	(9)
1991[b]							
3	11	0.054	(0.017)	126	(56)	321	(8)
4	15	0.074	(0.020)	171	(72)	375	(10)
5	30	0.149	(0.030)	343	(131)	394	(6)
6	27	0.130	(0.027)	299	(111)	473	(11)
7	29	0.129	(0.024)	299	(101)	511	(15)
8	58	0.208	(0.031)	481	(109)	571	(9)
9	29	0.101	(0.022)	234	(60)	560	(31)
10	36	0.116	(0.028)	267	(63)	619	(22)
11	6	0.018	(0.007)	41	(18)	657	(38)
12	7	0.021	(0.008)	47	(20)	791	(40)
1992[b]							
3	51	0.19	(0.025)	538	(111)	352	(7)
4	87	0.31	(0.031)	892	(164)	422	(7)
5	75	0.21	(0.023)	609	(97)	533	(9)
6	44	0.11	(0.017)	307	(55)	601	(12)
7	45	0.09	(0.017)	268	(47)	652	(10)
8	19	0.04	(0.010)	112	(28)	651	(13)
9	20	0.04	(0.009)	113	(27)	698	(16)
10	4	0.01	(0.004)	23	(11)	779	(35)
11	1	<0.01	(0.002)	6	(6)	769	

[a] Estimates were made using inter-seasonal data sets from 1990 and 1991. Sample sizes were from 1990.

[b] Estimates were made using intra-seasonal data sets from 1991 and 1992. Sample sizes were from Event 2 in 1991 and 1992.

Mean Length at Age

The mean length of northern pike generally increased with increasing age within a year (Table 14). However, mean length for a given age was highly variable between years.

Error in Age Determination

The error in age determination for the 1990-1991 data set ranged from -1 (under aged) to 4 years (over aged) and the mode was 2 years (Appendix B, Figure 6). The error in age determination for the 1991-1992 data set ranged from -6 to 1 years and the mode was -2 years (Appendix C).

Mean Growth

Mean growth of northern pike by 50 mm length intervals was similar from 1990 to 1991 and 1991 to 1992 (Figure 7). Ninty-three northern pike captured in 1990 were captured again in 1991. No length was recorded for three of these fish. Mean growth of northern pike equal to 300 mm and longer ranged from 144 mm for smaller fish to 47 mm for larger fish. One hundred seventeen northern pike captured in 1991 were captured again in 1992. Only 114 fish were used in the analysis because no length was recorded for one fish and lengths for two fish in 1992 were less than the cut off point for recruitment (443 mm). Mean growth of northern pike equal to 300 mm and longer ranged from 143 mm for smaller fish to 36 mm for larger fish. Growth was not estimated by sex due to the difficulty of determining sex during the capture events.

Survival and Recruitment

The rate of survival for the population of northern pike from 1990 to 1991 was 0.97 (SE = 0.18, Table 15). The instantaneous rate of mortality during the same period was 0.033. The rate of recruitment during 1991 to 1992 was 2.23 (SE = 0.33). The instantaneous rate of recruitment during the same period was 0.803.

Tag Loss

In 1991, of the 19 marked fish recovered during the second event all had Floy tags and fin clips. However, during the second event, four northern pike were captured more than once and had lost their tags. Double finclips indicated that these fish were captured and marked in the first event and were then captured at least twice during the second event. The Floy tags were lost sometime after the fish were first recaptured during the second event. One tag was found in a net where a northern pike had escaped through the mesh. Two northern pike recovered in 1992 had lost Floy tags some time during the mark-recapture experiment. Both northern pike had fin punches from the first event but not the second event. We could not determined if northern pike marked in 1990 and 1991 had lost Floy tags because all marked northern pike had regenerated their fins.

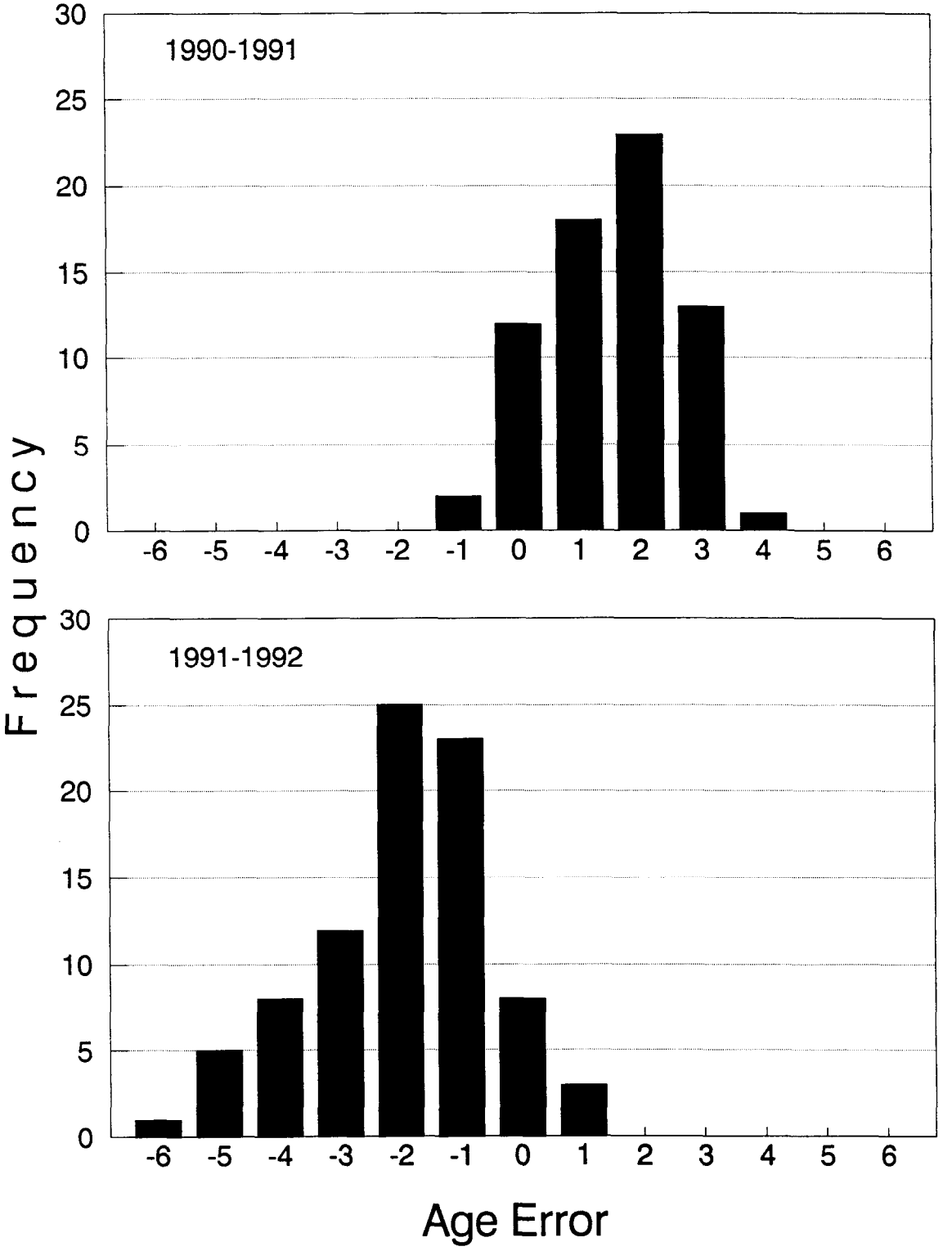

Figure 6. Age error of northern pike for 1990-1991 and 1991-1992.

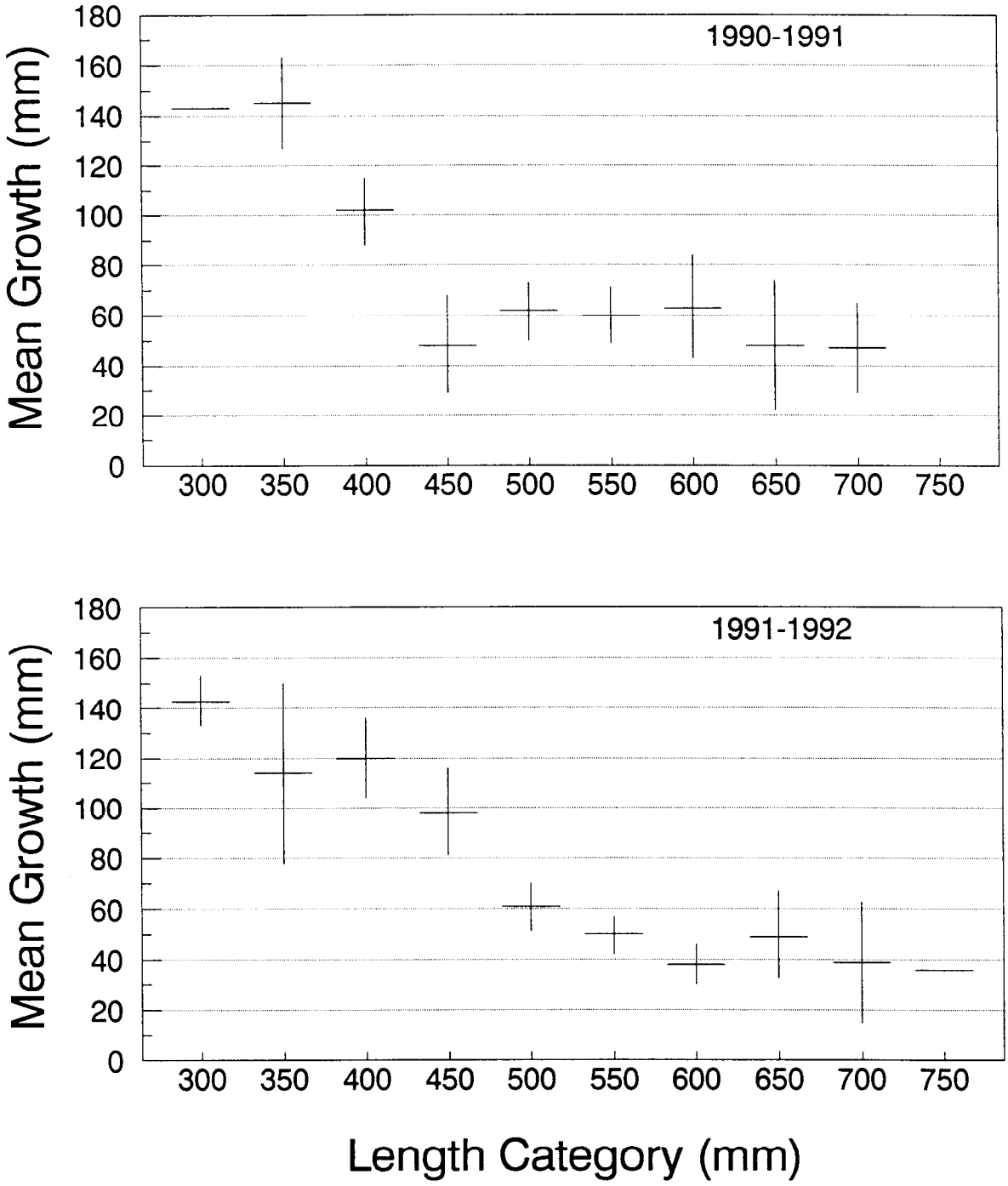

Figure 7. Mean growth (with 95% confidence intervals) by 50 mm length categories for northern pike captured in 1990 and recovered in 1991 and captured in 1991 and recovered in 1992 during mark-recapture experiments in Harding Lake.

Table 15. Estimates of rates of survival and recruitment from a triple-catch experiment using Bailey's method.

Time	New Marks	Examined for Marks	Recaps from 1990	Recaps from 1991
1990	570			
1991	340	433	93	
1992		768	73	44

Survival rate from 1990 to 1991:	0.97
Standard Error:	0.18
Recruitment rate from 1991 to 1992:	2.23
Standard Error:	0.33

Location and Movement of Northern Pike in 1992

Northern pike captured in the vegetation zone generally were recaptured within the zone. However, there was considerable movement within the zone from location of capture to location of recapture (Figure 8). Several northern pike did move more than 1 km and there was some movement into and out of the vegetation zone and across the lake. Between Event 1 and Event 2, more northern pike moved greater distances compared to distances moved during Event 1 (Figure 9). Also, during Event 2, a greater proportion of the northern pike captured and recaptured moved greater distances compared to Event 1 (Figure 10). The relationship between distance and time intervals between captures was not investigated for this report. Results of a study of movement of northern pike in Harding Lake will be presented in another report.

Of the 26 northern pike captured and fitted with radio tags, females (12) were captured in the vegetation zone near the east inlet only. Males (14) were captured throughout the vegetation zone.

Statistics from other Studies

In 1991 and 1992, 85 northern pike were captured in gill nets and fyke traps during a project to evaluate stocked game fish in Harding Lake. Statistics for these fish are listed in Appendix D.

DISCUSSION

Abundance was estimated with intra-seasonal and inter-seasonal data sets to determine if the two methods gave different estimates. A large difference between estimates for a given year would indicate that at least one of the estimates is biased. A small difference would indicate that there was probably no significant bias for either method. Because estimates of abundance were similar for a given year, there was probably no significant bias with either method. Also, the unstratified estimates of abundance were similar to the stratified estimates.

Statistical tests used to evaluate bias during the mark-recapture experiment in 1991 indicated significant failure of the assumptions for the abundance estimator. An estimate may be biased due to violations of the three assumptions associated with the model for the two-sample mark-recapture experiments. For the model to be valid only one of these three assumptions must be satisfied.

In 1991, too few northern pike (six) were marked and released in Section II to anticipate recovering adequate numbers of these fish during the second sampling event; and, none were recaptured. Although reasonable numbers of fish were marked and released in Section I during the first sampling event, most of these fish were also recovered in Section I during the second event and the number recovered was not proportional to the number of fish captured by section. Also, we only can say some mixing occurred (at least some fish marked in Section I during the first sampling event moved into Section II

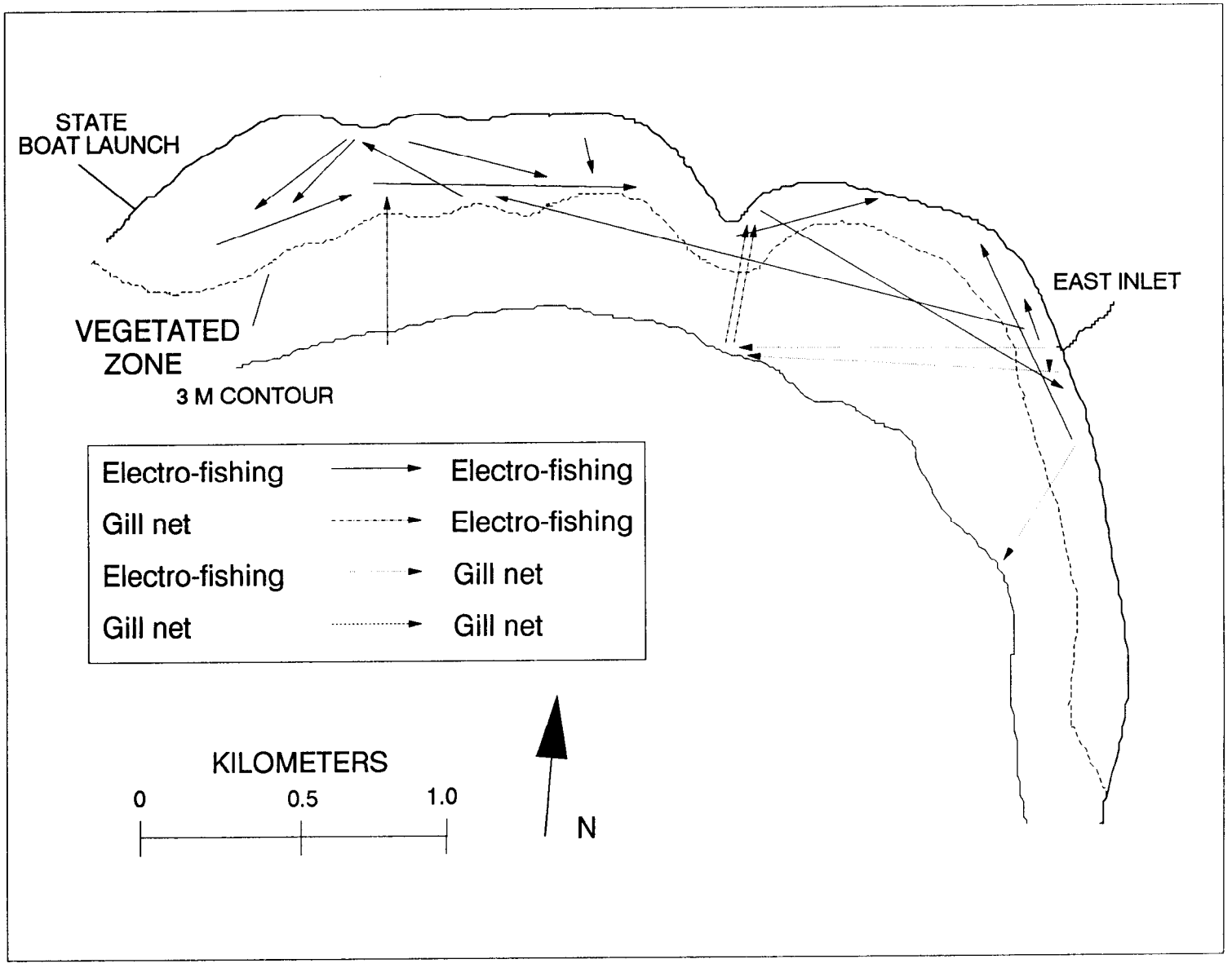

Figure 8. Location and Movement of northern pike captured and recovered during Event 1 of the mark-recapture experiment in 1992.

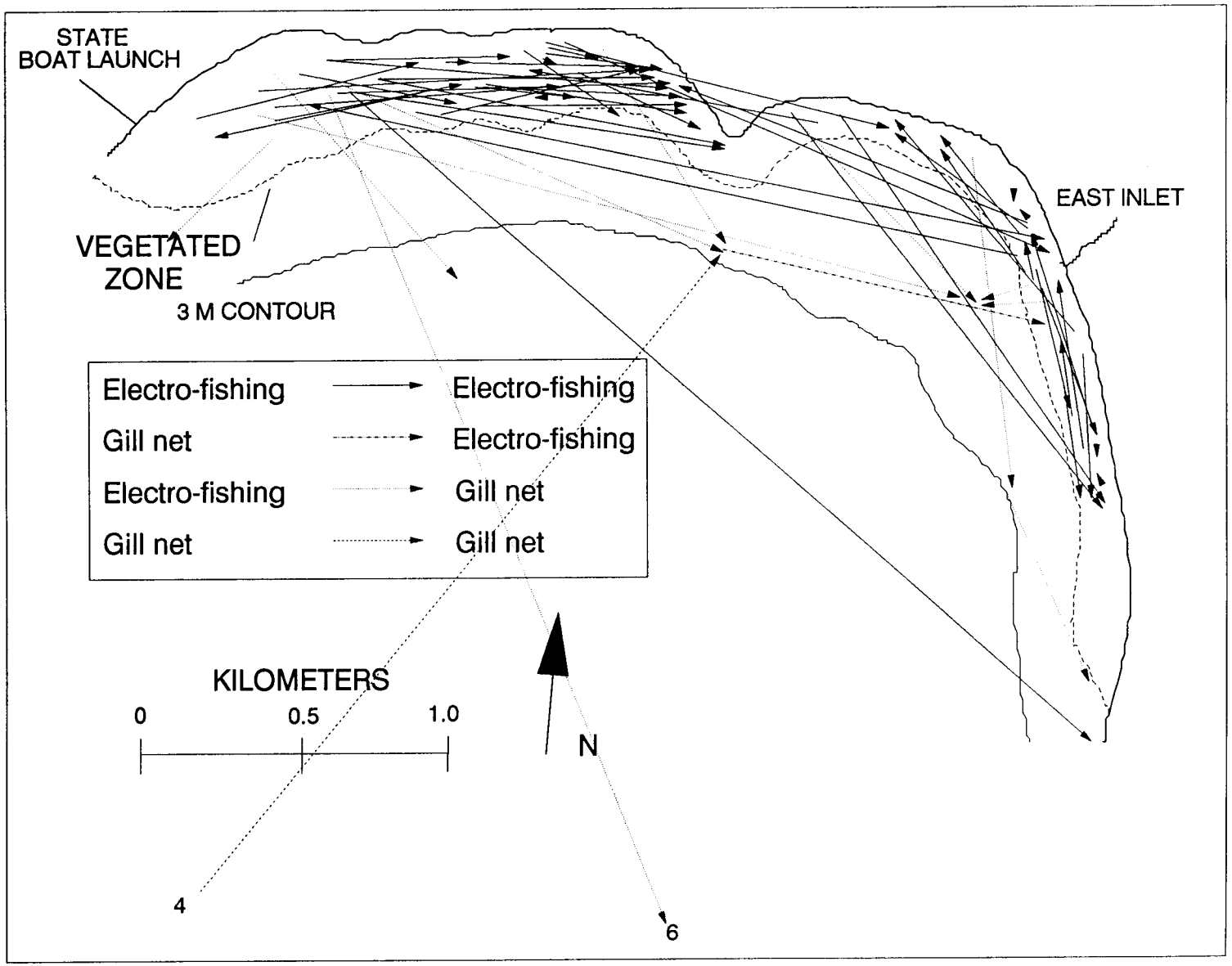

Figure 9. Location and Movement of northern pike captured and Event 1 and recovered during Event 2 of the mark-recapture experiment in 1992.

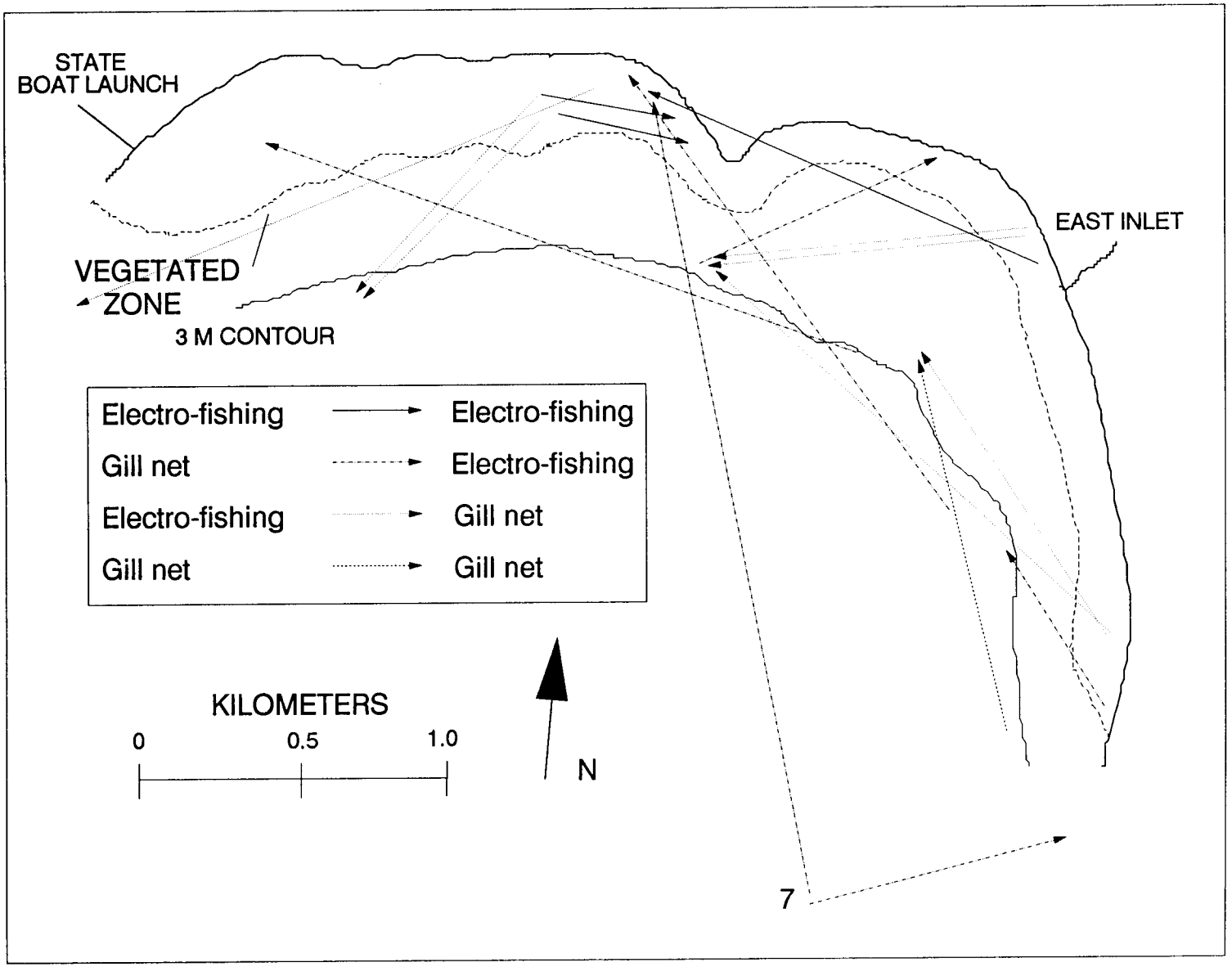

Figure 10. Location and Movement of northern pike captured and recovered during Event 2 of the mark-recapture experiment in 1992.

during the second sampling event), but mixing was likely not complete. As a result, the estimate of abundance in 1991 was questionable without a comparison to another estimate. In 1990, we only were able to estimate abundance of northern pike 450 mm and longer because no marked fish 300 mm to 450 mm were recovered. However, by using inter-seasonal data sets we were able to check the intra-seasonal estimates of abundance in 1990 and 1991 and estimate the abundance of northern pike 300 mm and longer in 1990.

During the mark-recapture experiments in 1990, 1991, and 1992 more northern pike were captured consistently in less time during Event 2. During Event 1 we were restricted to capturing northern pike only in the vegetation zone. However, during Event 2 when the lake was ice-free, more northern pike were captured in less time in the vegetation zone and gill nets to could be used to capture northern pike in other areas. These capture rates suggest that a portion of the northern pike population moved into the vegetation zone after Harding Lake was ice-free. We recommend that future mark-recapture experiments in Harding Lake be conducted after the lake is ice-free. This modification will increase the number of fish captured in Event 1 and will better distribute effort around Harding Lake during both events. This will likely reduce the time needed to perform mark-recapture experiments and prevent problems similar to those encountered when analyzing the 1991 data set.

Since 1990, the abundance of northern pike (300 mm and longer) in Harding Lake has increased from about 2,000 to about 2,800 in 1992. Most of this increase occurred from 1991 to 1992 and was due to an increase in the abundance of small (300 mm to 449 mm) northern pike. This increase may be due to changes made to fishing regulations for Harding Lake or to environmental factors that affect survival of young northern pike. Kipling and Frost (1970) suggest temperature and growth during the first year effect survival. The abundance of larger northern pike (450 mm and longer) has remained about 1,500 since 1990. Although the number of angler-days for Harding Lake reached a new high in 1991, the abundance of small fish increased while the abundance of large fish was constant.

The rate of survival of northern pike in Harding Lake from 1990 to 1991 was high and may be the result of the unusually small harvest in 1990. The rate of recruitment suggests a large portion of the population in 1992 was comprised of recruits which supports the finding of increased abundance of small northern pike compared to previous years.

The estimated length composition of the population in 1990, 1991, and 1992 probably under-estimates the abundance of small northern pike (<450 mm). Smaller and younger northern pike were more abundant than larger and older northern pike in a Scottish lake (Munro 1957). Young northern pike were also under represented in catches of northern pike in Windermere (Kipling and Frost 1970). Small northern pike in Harding Lake probably were less likely to be captured because the mesh size of some of the panels used in the variable mesh gill nets were too large to capture small northern pike or behavior was different for small and large northern pike or both. Small northern pike were observed to pass through or escape from the larger mesh sizes. However, these estimates of abundance can be used to compare length compositions between

years because capture gear and methods were similar. Northern pike are probably fully recruited to the capture gear used in these mark-recapture experiments at 550 mm based on the length frequency of catches of northern pike.

The estimated age composition of the population in 1990, 1991, and 1992 are not reliable because smaller and younger northern pike were probably under-represented in the catches. Also, there was difficulty in determining the age of northern pike from scales as indicated by the degree of error found for the population of northern pike in Harding Lake and in other Alaskan populations of northern pike (Pearse and Hansen 1992). Casselman (1978) reported that northern pike may absorb the outer portions of their scales which would cause the age of northern pike to be under estimated. Casselman (1974, 1979) showed that cleithra yield more accurate results than scales. Lane et al. (1991) found that scales and cleithra were equally suitable for estimating the age of northern pike; however, cleithra were more accurate for northern pike older than age 10. The determination of the age error associated with increasing age was not investigated for the northern pike population in Harding Lake.

Estimates of mean length at age were probably not reliable because of the difficulty of determining the age of northern pike from scales. The shift of the mode from over estimates by two years to under estimates by two years indicated that the ages for northern pike were not reliable. Therefore, estimates that depend on age were not reliable. Although the distribution of age errors when combined across years was normally distributed with a mode of about 0, the variability between years does not allow for valid comparisons between years.

Densities of northern pike (number per surface hectare) in Harding Lake between 1990 and 1992 are some of the lowest reported for any interior Alaskan lake (Pearse 1991). This may be an artifact of Harding Lake's morphology. Northern pike live in shallow water and probably do not occupy the deeper portions of the lake. Northern pike in Harding Lake were not usually captured deeper than 20 m. The density of northern pike should probably be estimated using surface hectares for water less than 20 m.

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LITERATURE CITED

Bailey, N. J. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38: 293-306.

Burkholder, A. 1991. Abundance and composition of northern pike, Harding Lake, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-9, Anchorage. 33 pp.

Casselman, J. M. 1974. Analysis of hard tissue of pike (Esox Lucius) with special reference to age and growth. T. B. Bagenal, editor. The ageing of fish. Unwin Brothers, Surrey, UK. 13-27.

Casselman, J. M. 1978. Calcified tissue and body growth of northern pike, Esox lucius Linnaeus. University of Toronto. Thesis. 579 pp.

Casselman, J. M. 1979. The esocid cleithrum as an indicator of calcified tissue. Proceedings of the 10th warmwater workshop. J. Dube and Y. Gravel, editors. American Fisheries Society, Northeastern Division. Ministry of Tourism, Montreal. 249-272.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. No. 1:131-160.

Clark, J. H. 1988. Abundance and life history features of the T Lake northern pike population during 1986 and 1987. Alaska Department of Fish and Game, Fishery Data Series No. 47, Juneau. 44 pp.

Frost, W. E., and C. Kipling. 1959. The determination of the age and growth of pike (Esox lucius L.) from scales and opercular bones. Journal Cons. Int. Explor. Mer 24:314-341.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management, 4: 273-285.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association, 55: 708-713.

Kipling, C. and W. E. Frost. 1970. A study of the mortality, population numbers, year class strengths, production and food consumption of pike, Esox Lucius L., in Windermete from 1944 to 1962. Journal of Animal Ecology 39: 115-157.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20(SW-I-A). 122 p.

_____. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21(SW-I-A). 65 pp.

_____. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 77 pp.

_____. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 107 pp.

_____. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A). 115 pp.

_____. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A). 118 pp.

_____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A). 123 pp.

_____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A). 137 pp.

_____. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2). 137 pp.

_____. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau. 140 pp.

_____. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau. 95 pp.

_____. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game,. Fishery Data Series No. 122, Juneau, 142 pp.

_____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game. Fishery Data Series No. 90-44, Anchorage. 152 pp.

_____. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game. Fishery Data Series No. 91-58, Anchorage. 184 pp.

_____. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game. Fishery Data Series No. 92-40, Anchorage. 189 pp.

Munro, W. R. 1957. The pike of Loch Choin. Freshwater Salmon Fishery Research 16: 16 p.

Pearse, G. A. 1991. Stock assessment of the northern pike populations in Volkmar, George, and T Lakes, 1990 and 1991, and a historical review of research conducted since 1985. Alaska Department of Fish and Game, Fishery Data Series No. 91-63, Juneau. 81 pp.

Pearse, G. A. and P. A. Hansen. 1992. Evaluations of age determination in Alaskan northern pike. Alaska Department of Fish and Game, Fishery Data Series No. 92-4, Anchorage. 28 pp.

Peckham, R. D. and D. R. Bernard. 1987. Northern pike abundance and composition study. Alaska Department of Fish and Game, Fishery Data Series No. 27, Juneau. 45 pp.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191: 382 pp.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffin and Company Limited, High Wycombe Bucks, England. 654 pp.

Williams, J. E. 1955. Determination of age from the scales of northern pike (*Esox lucius* L.). Ph. D. Thesis, University of Michigan, Ann Arbor. 185 pp.

APPENDIX A

Detecting bias and unequal probabilities of capture during sampling of fish populations.

Appendix A. Detecting bias and unequal probabilities of capture during sampling of fish populations.

Part I. INFERENCE AS A MEANS TO DETECT BIAS DUE TO GEAR SELECTIVITY

Results of Hypothesis Tests (K-S and v^2) on Lengths of Fish Marked during First First Event and Recaptured during Second Event	Results of Hypothesis Tests (K-S) on Lengths of Fish Captured during First Event and during Second Event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_o	Reject H_o
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

-continued-

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified abundance estimates for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias to data from the second event.

Case IVb: If the stratified and unstratified abundance estimates for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

PART II. UNEQUAL PROBABILITIES OF CAPTURE FOR FISH IN DIFFERENT PARTS OF THE LAKE OR FAILURE OF MARKED FISH TO MIX COMPLETELY WITH UNMARKED FISH

- If the fraction of the population comprised of marked fish is similar in all areas of the lake or stream, either every fish had an equal chance of being caught during the FIRST EVENT or marked fish mixed completely with unmarked fish BETWEEN EVENTS. In either case, "OR" conditions have been met and no correction is needed.

- If the fraction in the population comprised of marked fish is dissimilar among areas of the lake or stream, there is no evidence that "OR" conditions have been met:

- If inspection of data shows marked fish did not move from area to area between sampling events, estimate abundance for each area of the stream or lake. A minimum estimate of abundance is the sum of the estimates across the areas.

- If inspection of data shows marked fish did move from area to area, estimate abundance with the method of Darroch (1961) for the entire population.

APPENDIX B

Growth and age error of northern pike captured in Harding Lake from 1990 to 1991.

Appendix B. Growth and age error of northern pike captured in Harding Lake from 1990 to 1991.

Tag	1990 Length (mm)	1990 Age	1991 Length (mm)	1991 Age	1990 - 1991 Growth (mm)	1990 - 1991 Age Error
4296	580	8	612	11	32	2
62770	604	7	.	10	.	2
62776	567	7	677	8	110	0
62778	718	8	781	9	63	0
62780	635	7	.	.	.	.
62784	494	5	564	8	70	2
62800	605	6	682	.	77	.
62807	554	6	602	.	48	.
62820	547	.	560	8	13	.
62827	685	7	720	.	35	.
62831	442	5	523	10	81	4
62834	596	7	602	.	6	.
62840	401	4	487	6	86	1
62848	518	6	565	8	47	1
62854	580	7	613	8	33	0
62857	421	4	493	6	72	1
62858	570	6	669	10	99	3
62873	551	6	598	9	47	2
62874	586	6	637	7	51	0
62879	519	6	553	8	34	1
62883	692	9	766	9	74	-1
62885	531	7	590	11	59	3
62905	504	5	588	.	84	.
62914	581	8	612	10	31	1
62917	654	8	689	11	35	2
62934	514	6	591	8	77	1
62936	526	.	.	9	.	.
62937	505	5	549	9	44	3
62939	.	.	765	8	.	.
62942	505	6	592	.	87	.
62949	715	7	595	9	-120	1
62954	399	5	530	8	131	2
62974	584	6	665	9	81	2
62975	511	6	573	8	62	1
62977	589	7	621	10	32	2
62980	453	6	492	7	39	0
62981	590	7	629	10	39	2
62986	406	4	530	7	124	2
62996	426	5	534	7	108	1
62997	485	5	503	.	18	.
62998	440	5	548	9	108	3
63561	534	6	628	7	94	0
63564	539	7	557	.	18	.

- continued -

Appendix B. (Page 2 of 3).

Tag	1990 Length (mm)	1990 Age	1991 Length (mm)	1991 Age	1990 - 1991 Growth (mm)	1990 - 1991 Age Error
63567	457	5	474	.	17	.
63577	535	5	595	8	60	2
63589	426	5	519	8	93	2
63592	575	7	618	10	43	2
63593	388	3	515	6	127	2
63600	607	6	646	10	39	3
63615	616	7	645	10	29	2
63617	632	8	718	8	86	-1
63626	632	7	682	.	50	.
63628	613	6	678	.	65	.
63629	668	7	611	.	-57	.
63633	534	6	564	8	30	1
63635	528	6	581	.	53	.
63637	714	9	746	12	32	2
63638	575	7	679	8	104	0
63645	586	6	678	8	92	1
63663	398	.	560	6	162	.
63669	512	6	556	7	44	0
63672	623	7	654	10	31	2
63673	638	6	721	10	83	3
63678	507	5	592	.	85	.
63679	490	.	572	.	82	.
63808	561	7	661	10	100	2
63813	518	6	610	10	92	3
63814	613	7	647	10	34	2
63816	587	6	666	10	79	3
63817	592	7	697	8	105	0
63824	579	7	626	9	47	1
63825	553	6	637	10	84	3
63827	509	6	590	8	81	1
63834	542	7	592	10	50	2
63839	430	5	542	9	112	3
63851	415	4	548	8	133	3
63852	560	7	630	8	70	0
63853	565	7	587	11	22	3
63856	575	7	623	.	48	.
63859	363	4	522	7	159	2
63871	550	6	625	8	75	1
63874	702	9	748	12	46	2
63883	471	5	518	7	47	1
63892	560	6	616	7	56	0
63898	545	.	600	9	55	.
63900	475	6	541	7	66	0
63926	642	7	696	10	54	2

- continued -

Appendix B. (Page 3 of 3).

Tag	1990 Length (mm)	1990 Age	1991 Length (mm)	1991 Age	1990 - 1991 Growth (mm)	1990 - 1991 Age Error
63931	579	7	628	9	49	1
63950	506	6	632	10	126	3
63951	589	7	630	9	41	1
63955	506	6	567	8	61	1
63961	639	8	785	.	146	.
63982	332	.	475	6	143	.

APPENDIX C

Growth and age error of northern pike captured in Harding Lake from 1991 to 1992.

Appendix C. Growth and age error of northern pike captured in Harding Lake from 1991 to 1992.

Tag	1991 Length (mm)	1991 Age	1992 Length (mm)	1992 Age	1991 - 1992 Growth (mm)	1991 - 1992 Age Error
4385	633	.	692	.	59	.
62770	.	10	682	9	.	-2
62776	677	8	743	7	66	-2
62807	602	.	643	7	41	.
62827	720	.	783	8	63	.
62834	602	.	620	6	18	.
62840	487	6	551	6	64	-1
62848	565	8	608	.	43	.
62854	613	8	649	7	36	-2
62874	637	7	688	8	51	0
62883	766	9	802	9	36	-1
62942	592	.	627	6	35	.
62975	573	8	613	8	40	-1
63592	618	10	663	7	45	-4
63615	645	10	663	11	18	0
63635	581	.	641	7	60	.
63637	746	12	769	11	23	-2
63638	679	8	737	7	58	-2
63678	592	.	614	6	22	.
63808	661	10	722	6	61	-5
63814	647	10	665	.	18	.
63817	697	8	760	6	63	-3
63834	592	10	672	8	80	-3
63900	541	7	586	7	45	-1
63926	696	10	720	9	24	-2
63931	628	9	676	8	48	-2
63950	632	10	716	8	84	-3
63951	630	9	657	8	27	-2
63955	567	8	611	8	44	-1
63961	785	.	709	8	-76	.
64000	546	.	625	8	79	.
64007	566	8	589	7	23	-2
64011	532	8	605	6	73	-3
64013	468	7	560	7	92	-1
64020	511	9	597	6	86	-4
64022	573	10	596	7	23	-4
64023	609	6	644	6	35	-1
64025	558	8	631	6	73	-3
64027	526	7	575	6	49	-2
64030	660	12	725	8	65	-5
64037	560	8	645	5	85	-4
64041	634	8	691	9	57	0
64046	662	9	623	7	-39	-3

- continued -

Appendix C. (Page 2 of 3).

Tag	1991 Length (mm)	1991 Age	1992 Length (mm)	1992 Age	1991 - 1992 Growth (mm)	1991 - 1992 Age Error
64055	617	10	652	9	35	-2
64057	312	3	462	.	150	.
64062	420	6	507	6	87	-1
64068	323	4	451	4	128	-1
64069	402	5	529	4	127	-2
64070	583	9	684	5	101	-5
64073	618	9	645	9	27	-1
64078	451	.	629	9	178	.
64084	561	.	612	7	51	.
64086	623	8	640	8	17	-1
64087	608	10	638	9	30	-2
64088	524	8	573	9	49	0
64092	587	.	642	5	55	.
64097	441	6	531	5	90	-2
64404	681	9	692	7	11	-3
64412	424	6	539	5	115	-2
64415	453	.	547	6	94	.
64704	577	.	606	7	29	.
64705	426	6	531	6	105	-1
64715	366	5	462	6	96	0
64719	404	.	543	4	139	.
64727	596	.	658	9	62	.
64729	378	7	510	4	132	-4
64805	518	8	584	5	66	-4
64812	309	5	431	5	122	-1
64814	457	.	530	7	73	.
64820	536	.	572	8	36	.
64834	524	10	593	6	69	-5
64838	577	9	608	7	31	-3
64841	562	.	630	6	68	.
64843	466	7	539	7	73	-1
64844	568	8	615	7	47	-2
64845	570	7	618	7	48	-1
64853	494	.	627	6	133	.
64857	565	10	598	6	33	-5
64858	571	.	614	7	43	.
64864	481	8	575	7	94	-2
64866	747	.	779	9	32	.
64869	536	9	625	9	89	-1
64870	404	4	546	6	142	1
64873	491	8	637	7	146	-2
64874	437	6	613	6	176	-1
64878	473	6	568	5	95	-2
64883	476	6	551	5	75	-2
64901	547	8	592	.	45	.

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Appendix C. (Page 3 of 3).

Tag	1991 Length (mm)	1991 Age	1992 Length (mm)	1992 Age	1991 - 1992 Growth (mm)	1991 - 1992 Age Error
64908	305	3	456	4	151	0
64913	550	7	588	7	38	-1
64914	520	9	570	7	50	-3
64916	640	12	660	7	20	-6
64918	560	7	.	.	.	.
64920	590	7	625	6	35	-2
64923	625	9	651	8	26	-2
64926	402	.	495	6	93	.
64929	525	6	565	7	40	0
64934	592	8	625	5	33	-4
64938	345	3	486	5	141	1
64940	452	7	585	.	133	.
64943	603	8	637	8	34	-1
64944	432	6	550	4	118	-3
64945	521	7	597	5	76	-3
64948	447	7	515	7	68	-1
64951	589	10	648	7	59	-4
64956	470	8	563	6	93	-3
64964	320	4	480	6	160	1
64970	305	.	452	4	147	.
64973	455	6	535	5	80	-2
64974	428	.	596	5	168	.
64979	447	5	574	4	127	-2
64990	604	6	682	6	78	-1
64992	492	7	545	8	53	0
64993	438	6	560	5	122	-2
64995	612	9	639	9	27	-1
64999	550	8	608	8	58	-1
71271	567	.	642	7	75	.

APPENDIX D

Statistics for northern pike captured during other studies in Harding Lake, 1991 and 1992.

Appendix D. Statistics for northern pike captured during other studies in Harding Lake, 1991 and 1992.

Date	Tag Number[a]	Length (mm)	
17 Sep 91	64891	804	
17 Sep 91	64892	596	
17 Sep 91	63639	706	
17 Sep 91		201	
18 Sep 91		284	
18 Sep 91		283	
18 Sep 91		125	
19 Sep 91	64425	356	
19 Sep 91		189	
19 Sep 91	64423	472	
19 Sep 91	63619	652	
19 Sep 91	64422	654	
20 Sep 91	64427	546	
20 Sep 91	64428	522	
21 Sep 91	64848	418	
21 Sep 91		132	
21 Sep 91	64893	554	
21 Sep 91	64894	563	
21 Sep 91		204	
21 Sep 91		124	
22 Sep 91		151	
22 Sep 91	64895	403	
22 Sep 91		154	
22 Sep 91	64896	363	
23 Sep 91	64430	329	
23 Sep 91		777	Killed
23 Sep 91	64429	338	
24 Sep 91	64433	507	
25 Sep 91	64435	675	
17 Sep 91	64891	804	
25 Aug 92		649	
25 Aug 92	62954	725	Killed
25 Aug 92	657	540	Killed
25 Aug 92	62844	925	
25 Aug 92	64901	646	Killed
25 Aug 92	901	678	
25 Aug 92	904	515	
25 Aug 92		662	Killed
25 Aug 92	64406	695	Killed
25 Aug 92		510	Killed
25 Aug 92	863	483	Killed
25 Aug 92	906	426	
25 Aug 92	907	446	

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Appendix D. (Page 2 of 2).

Date	Tag Number[a]	Length (mm)	
25 Aug 92	444	740	
25 Aug 92	64920	670	
25 Aug 92	908	813	
25 Aug 92	64006	735	
25 Aug 92	63844	668	
25 Aug 92	909	640	
25 Aug 92		740	Killed
25 Aug 92		770	Killed
26 Aug 92	64010	640	
26 Aug 92	622	575	
26 Aug 92	912	605	
26 Aug 92	913	435	
26 Aug 92	918	425	
28 Aug 92	187		
28 Aug 92	214		
28 Aug 92	64017	624	
28 Aug 92	930	441	
28 Aug 92	931	354	
28 Aug 92	64868	585	
28 Aug 92	927	468	
28 Aug 92	928	459	
28 Aug 92	929	336	
1 Sep 92	547	480	
1 Sep 92	566	599	
1 Sep 92	692	614	Killed
1 Sep 92	687	603	
1 Sep 92	943	387	
1 Sep 92	857	617	
1 Sep 92	509	540	
1 Sep 92	64055	664	
2 Sep 92	961	482	
2 Sep 92	954	557	
2 Sep 92	955	305	
3 Sep 92	963	459	
3 Sep 92	964	430	
3 Sep 92	358	366	
3 Sep 92	968	460	
3 Sep 92	287		
4 Sep 92	64007	626	
4 Sep 92	64062	534	
4 Sep 92	641	566	
4 Sep 92	971	498	
4 Sep 92	705	627	

[a] Northern pike less than 300 mm were not tagged.